APPENDIX A

Total Maximum Daily Load of
Phosphorus for
The Marshyhope Creek
Dorchester and Caroline Counties, Maryland

Report Version: December 15, 2001

Appendix A

MODELING FRAMEWORK

The computational framework chosen for the modeling of water quality in the Marshyhope Creek was the Water Quality Analysis Simulation Program version 5.1 (WASP5.1). This program provides a generalized framework for modeling contaminant fate and transport in surface waters (Di Toro *et al*, 1983) and is based on the finite-segment approach. It is a very versatile program, capable of being applied in a time-variable or steady-state mode, spatial simulation in one, two or three dimensions, and using linear or non-linear estimations of water quality kinetics. To date, WASP5.1 has been employed in many modeling applications that have included river, lake, estuarine and ocean environments. The model has been used to investigate water quality concerns regarding dissolved oxygen, eutrophication, and toxic substances. WASP5.1 has been used in a wide range of applications by regulatory agencies, consulting firms, academic researches and others.

WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al*, 1988). EUTRO5.1 is the component of WASP5.1 that is applicable for modeling eutrophication, incorporating eight water quality constituents in the water column (Figure A1) and sediment bed.

WATER QUALITY MONITORING

Physical and chemical samples were collected by MDE's Field Operations Program staff on February 16, March 25, April 8, July 15, August 5, and September 9, 1998. The physical parameters, dissolved oxygen, salinity, conductivity, and water temperature were measured *in situ* at each water quality monitoring station. Grab samples were also collected for laboratory analysis. The samples were collected at a depth of ½ m from the surface. Samples were placed in plastic bottles and preserved on ice until they were delivered to the University of Maryland Laboratory in Solomons, MD, or the Department of Health & Mental Hygiene in Baltimore, MD for analysis. The field and laboratory protocols used to collect and process the samples are summarized in Table A1. The February and March data were used to calibrate the high flow water quality model, April data was not included because of significant difference between February-March data and April data temperature. July, August and September data were used to calibrate the low flow water quality model for the Marshyhope Creek. Figures A2 – A6 present low flow and high flow water quality profiles along the river.

MODEL INPUT REQUIREMENTS [1]

Model Segmentation and Geometry

The spatial domain of the Marshyhope Creek Eutrophication Model (MCEM) extends from the confluence of the Marshyhope Creek and the Nanticoke River for about 38 miles (60 km) up the mainstem of the Creek. Following a review of the bathymetry for Marshyhope Creek, the model was divided into 23 segments. Figure A7 shows the model segmentation for the development of MCEM. Table A2 lists the volumes, characteristic lengths and interfacial areas of the 23 segments.

Dispersion Coefficients

The dispersion coefficients were calibrated using the WASP5.1 model and in-stream water quality data from 1998. The WASP5.1 model was set up to model salinity. Salinity is a conservative constituent, which means there are no losses due to reactions in the water. The only source in the system is the salinity from the water at the tidal boundary at the mouth. For the model execution, salinity values at all boundaries except the tidal boundary were set to zero. Flows were obtained from regression equation for both low flow and high flow using data from USGS gage station near Adamsville, Maryland. Figure A8 shows the results of the calibration of the dispersion coefficients for low flow. The same sets of dispersion coefficients were used for both high flow and low flow calibration, because of insufficient salinity data for a reasonable high flow salinity calibration. Final values of the dispersion coefficients are listed in Table A3.

Freshwater Flows

Freshwater flows were calculated on the basis of delineating the Marshyhope Creek drainage basin into 39 subwatersheds (Figure A9). These subwatersheds closely correspond with the Maryland Department of Natural Resources 12-digit basin codes. Where necessary, the subwatersheds were refined to assure they were consistent with the 23 segments developed for the MCEM. The MCEM was calibrated for two sets of flow conditions: high flow and low flow. The high flow corresponds to the months of February and March, while the low flow corresponds to the months of July, August and September.

The high flow and the low flow for each subwatershed was estimated based on 30 years historical flow data from the USGS gage station 01488600 near Adamsville Delaware. Flows were calculated for high flow by averaging all the February and March flow data, and for low flow by averaging the daily July, August and September. The average flow was based on the same USGS data but all the months in the years 1987 through 1988 were averaged. These are the years on which Chesapeake Bay Program loads were used for the average flow scenario. A ratio of flow to drainage area was calculated from the USGS station data, then multiplied by the area of each of the subwatershed to estimate the high and low flows. For both high flow and low

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[1] The WASP model requires all input data to be in metric units, and to be consistent with the model, all data in the Appendix will appear in metric units except the river length. Following are several conversion factors to aid in the comparison of numbers in the main document: mgd x (0.0438) = m^3/s | cfs x (0.0283) = m^3/s | lb / (2.2) = kg | mg/l x mgd x (8.34) / (2.2) = kg/d

flow, each sub-watershed was assumed to contribute a flow to the Marshyhope Creek mainstem. These flows and loads were assumed to be direct inputs to the MCEM. Table A4 presents flows from different subwatersheds during high, low, and average conditions.

Nonpoint Source Loadings

Nonpoint source loadings were estimated for high flow, low flow and average annual flow conditions. For nonpoint sources, the concentrations of the nutrients nitrogen and phosphorus are modeled in their speciated forms. The WASP5.1 model simulates nitrogen as ammonia (NH_3), nitrate and nitrite (NO_{2-3}), and organic nitrogen (ON); and phosphorus as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algae growth, that can affect chlorophyll *a* levels and dissolved oxygen concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios represent values that have been measured in the field.

Loads for high flow and low flow calibration were estimated as the product of observed high flow and low flow 1998 concentrations and multiplied by their respective estimated flows described above. These nonpoint source loads for the calibration of the model were calculated using data from two water quality stations within the Marshyhope Creek Basin. Data from station MRH0006 was used as a boundary condition for segment 1 of the MCEM, and data from station MRH0311 was used as a boundary condition for segment 23. The boundary conditions for the remaining boundaries were based on average concentrations calculated using stations MRH0311 and SMD0003. These are the stations representing only freshwater nonpoint contributions in the watershed and they were assumed to be a reasonable representation of water quality in the tributaries. BOD data was not available for high flow, and was assumed to be 2.0 mg/l at all boundaries.

Average annual loads were determined using land use loading coefficients. The land use information was based on 1997 Maryland Office of Planning land cover data, adjusted using crop acres from 1997 Farm Service Agency (FSA) data, and on 1997 Delaware Office of Planning land cover data. The total nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients. The loading coefficients were based on the results of the Chesapeake Bay Model (U.S. EPA, 1996), a continuous simulation model. The Bay Model loading rates are consistent with what would be expected in the year 2000 assuming continued Best Management Practice (BMP) implementation at a level consistent with the current rate of progress.

Both calibration loads and average annual loads reflect natural and human sources, including atmospheric deposition, loads coming from septic tanks, loads coming from urban development, agriculture, and forestland.

Point Source Loadings

For point sources, the concentrations of all eight parameters considered are modeled in the same speciated forms as described above in the Nonpoint Source Loadings section.

Four point sources that discharge nutrients into the system were considered for the analysis. The Federalsburg WWTP discharges directly into the Marshyhope Creek. The Hurlock WWTP discharges into Wrights Branch. The Colonel Richardson Middle & High School WWTP discharges into Tull Branch. The only industrial facility, the W.O. Whiteley industry, discharges into an unnamed tributary. The W. O. Whiteley discharge, of less than an average of one gallon per day, was considered to be insignificant, and was dropped from further consideration.

The point source loadings used in the calibration of the model were calculated from actual WWTP flows and concentrations stored in MDE's point source database. For higher stream flow conditions, point source loads were simulated as an average of February and March 1998 discharge report data. For low flow stream conditions, point source loads were simulated as an average of July, August and September 1998 discharge report data. February, March, July, August and September 1998 data were used to be consistent with the time period of the water quality monitoring data.

Hurlock WWTP has a special discharge permit that requires the plant to do wastewater land irrigation during the summer months (May-October) instead of surface discharge into the river. When Hurlock is discharging directly to Wrights Branch, the 1998 data from MDE's Point Source database showed that the three plants together discharge approximately 47.7 pounds of nitrogen per day and 2.86 pounds of phosphorus per day into the river. Also, the plants together discharge an average of 1.12 millions of gallons of wastewater daily into the Marshyhope Creek. Most of this flow is contributed by Hurlock WWTP with an average flow of 0.78 millions of gallons per day. Table A5 presents the point source flows and loadings used for the model calibration.

The point source loadings used for the base-line "critical" scenario (first scenario) and for the annual average flow scenario (second scenario) were calculated from the maximum allowable effluent limits concentrations described in the plant's surface water discharge MDE permit (see scenarios description below). For model input parameters for which there is no maximum permit limit, concentrations were estimated based on the type of unit operations or treatment processes used by each plant under consideration.

Environmental Conditions

Eight environmental parameters were used for developing the model of the Marshyhope Creek. They are solar radiation, photoperiod, temperature (T), extinction coefficient (K_e), salinity, sediment oxygen demand (SOD), sediment ammonia flux (FNH_4), and sediment phosphate flux (FPO_4) (Table A6).

The light extinction coefficient, K_e in the water column was derived from Secchi depth measurements using the following equation:

$$K_e = \frac{1.95}{D_s}$$

where:

K_e = light extinction coefficient (m^{-1})
D_s = Secchi depth (m)

Nonliving organic nutrient components settle from the water column to the sediment at an estimated settling rate velocity of 0.086 *m/day*, and phytoplankton was estimated to settle through the water column at a rate of 0.0691 *m/day*. These values are within the range specified in the WASP5.1 manual. In general, it is reasonable to assume that 50% of the nonliving organics are in the particulate form. Such assignments were borne out through model sensitivity analyses.

Different SOD values were estimated for different MCEM reaches based on observed environmental conditions and literature values (Thomann, 1987). The lowest SOD values were assumed to occur in the marshy area upstream of the head of tide of the creek. This area is located downstream of a man made channelization of the creek where the creek spreads out into a marsh. It is assumed that the concentration of nutrients and chlorophyll *a* with the potential to settle will be settled and distributed over a larger area, diminishing the SOD values. A maximum SOD value of 0.5 $g\ O_2/m^2 day$ in most areas, and a minimum of 0.2 $g\ O_2/m^2 day$ was used throughout the marshy area (see table A6).

Kinetic Coefficients

The water column kinetic coefficients are universal constants used in the MCEM model. They are formulated to characterize the kinetic interactions among the water quality constituents. The initial values were taken from past modeling studies of Potomac River (Clark and Roesh, 1978; Thomann and Fitzpatrick, 1982; Cerco, 1985), and of Mattawoman Creek (Haire and Panday, 1985; Panday and Haire, 1986; Domotor *et al*., 1987), and the Patuxent River (Lung, 1993). The kinetic coefficients are listed in Table A7.

Initial Conditions

The initial conditions used in the model were chosen to reflect the observed values as closely as possible. However, because the model simulated a long period of time to reach equilibrium, it was found that initial conditions did not impact the final results.

CALIBRATION & SENSITIVITY ANALYSIS

The EUTRO5.1 model for low flow was calibrated with July, August and September 1998 data. Tables A8, A9 & A10 shows the nonpoint source flows and loads associated with the calibration input file (See *Point and Nonpoint Sources Loadings* above for details*).* Figures A10 – A17 show the results of the calibration of the model for low flow. As can be seen, in Figure 10 the model was able to replicate the BOD trend, although it did not capture the peak value. In Figure 11, the model did a good job of capturing the trend in the dissolved oxygen data. The ability to simulate the peak in chlorophyll a concentrations was limited by a value that was outside of the trend compare to the remaining observed concentrations (Figure A12). The model did an excellent job of capturing the peak in nitrate (Figure 13), and for organic nitrogen, the model followed the trend but did not capture the higher values (Figure 14). The ammonia concentrations trend was captured very precisely in the tidal part of the creek but not as accurately in the upstream waters (Figure A15). Figures 16 and 17 show how well the model simulated the organic phosphorus and the ortho-phosphate data.

The EUTRO5.1 model for high flow was calibrated with February and March 1998 data. The results are presented in Figures A18 to A25. As can be seen the model did well in capturing almost all the state variables. Two exceptions are the organic phosphorus and the ortho-phosphate; however, this is not significant given that the range of values is very small.

Model sensitivity analysis were performed on the calibration and on the baseline critical condition scenarios for low flow and average flow to determine the reaction of the model to reductions in both nitrogen and phosphorus. The model was sensitive to reductions in phosphorus. However, it was not sensitive to reductions in nitrogen. During low flow conditions a 100% increase in point source and nonpoint source total nitrogen loads had no effect on chlorophyll a or dissolved oxygen concentrations. During average flow the model did show a slight sensitivity to increased nitrogen. However it was very slight and did not affect the chlorophyll a or dissolved oxygen significantly. Thus when determining point source load reductions, only phosphorus was reduced.

SYSTEM RESPONSE

The EUTRO5.1 model of Marshyhope Creek was applied to several different nonpoint source loading conditions under various stream flow conditions to project the impacts of nutrients on algal production (modeled as chlorophyll *a*) and low dissolved oxygen. By simulating various stream flows, the analysis accounts for seasonality.

Model Run Descriptions

Baseline Condition Scenarios:

First scenario(Low Flow): represents the baseline critical low flow conditions of the stream. The low flow was estimated using a regression analysis as described above in the flows section. The nonpoint source loads for this scenario were the same nonpoint source loads used in the low flow calibration of the model and computed as described above in the "Nonpoint Source Loads" section. These nonpoint source loads are shown in Table A11. Because the loads are based on observed concentrations, they account for all background and human-induced sources. All the environmental parameters used for Scenario 1 remained the same as for the low flow calibration of the model. The point sources used in this scenario were calculated as described above in the section "Point Source Loadings" and are shown in Table A12.

Second scenario (Average Annual Flow): represents the expected conditions of the stream during average flow. The total average annual flow was estimated to be 229 cfs based on data from the USGS gage in the Marshyhope watershed as described above and are shown in Table A13. Nonpoint source load estimation methods, based on EPA Chesapeake Bay model output, are described above. Point source loadings were the same used in scenario 1. All the environmental parameters remained the same as Scenario 1 except for the temperature. Temperature for this scenario was estimated averaging the summer temperatures from Chesapeake Bay Program 12-year historical data in the Nanticoke River watershed. This summer average temperature of 28.5 ^{o}C was used for all segments, which is a conservative assumption. The boundary and initial conditions values for CHL*a*, DO, and BOD were assumed to be the same as for the low flow condition, because these data was not available.

Future Condition TMDL Scenarios:

Third scenario (Low Flow): is the final result of a number of iterative model scenarios involving nutrient reductions that were explored to determine the maximum allowable loads. The third scenario represents improved conditions associated with the maximum allowable loads to the stream during critical low flow. For this scenario, the flow was the same as scenario one. The total nonpoint source loads were based on the 1998 base-flow field data. The point source loads reflects the plant's maximum design flow and reduced effluent concentrations. All the environmental parameters (except nutrient fluxes and SOD) and kinetic coefficients used for the calibration of the model remained the same as Scenario 1. Description on the methods used to estimate the reduction of nonpoint and point sources as well as nutrient fluxes and SOD for this scenario are described in the following paragraphs.

- To estimate feasible nitrogen and phosphorus nonpoint source reductions, the percent of the nonpoint source load that is controllable was estimated for each subwatershed. It was assumed that all of the loads from cropland, feedlots, and urban were controllable, and that loads from atmospheric deposition, septic tanks, pasture, and forest were not controllable. This analysis was performed on the average annual loads, because loads from specific land uses were not available for low flow. However, the percent controllable was applied to the low flow loads as well as the average annual loads. A margin of safety of 5% was included in the load calculation. Using the above calculated percent controllable, several iterative reductions were made to the nonpoint source loadings starting with a 10% reduction of controllable loads up to the final 40% reduction used for the future low flow condition scenario. This 40% reduction in nonpoint source loads combined with the reductions in point source loads from the "baseline conditions" scenario met the chlorophyll *a* goal of 50 μ*g/l*, and the dissolved oxygen criterion of no less than 5.0 mg/l.

- The reduction in nutrients also affects the initial concentrations of chlorophyll *a* in the Creek for the model run. The amount of nitrogen and phosphorus available for algae growth was calculated after the reduction in nutrient loads, to help estimate the amount of chlorophyll *a* entering the boundaries. The amount of chlorophyll *a* that could be grown was calculated twice, once assuming nitrogen was the limiting nutrient, and again assuming phosphorus was the limiting nutrient. The lower of two values was compared to the low flow boundary value for chlorophyll *a*, and the lower of these two were then taken to be the boundary for average flow. All calculated values for the chlorophyll *a* boundaries were found to be higher than the low flow chlorophyll *a* boundaries and hence low flow chlorophyll *a* boundaries were used as a conservative assumption.

- The point sources loads were estimated using the plants' maximum design flow and reduced phosphorus loads. The phosphorus loads were reduced from the Scenario 1 "baseline conditions" to meet the chlorophyll *a* goal of 50 μ*g/l*, and the dissolved oxygen criterion of no less than 5.0 mg/l. Modeling input assumed the reduction would be implemented at major point sources (Design flow > 0.5 million of gallons per day) under anticipated summer operating conditions. More information about point sources loads can be found in the technical memorandum entitled "Significant Nutrient Point and Nonpoint Sources in the Marshyhope Creek Watershed".

- For the runs where the nutrient loads to the system were reduced, a method was developed to estimate the reductions in nutrient fluxes and SOD from the sediment layer. First, an initial estimate was made of the total organic nitrogen and organic phosphorus settling to the river bottom, from particulate nutrient organics, living algae, and phaeophytin, in each segment. This was done by running the expected condition scenario once with estimated settling of organics and chlorophyll *a*, then again with no settling. The difference in the amount of organic matter between the two runs was assumed to settle to the river bottom where it would be available as a source of nutrient flux and SOD. All phaeophytin was assumed to settle to the bottom. The amount of phaeophytin was estimated from in-stream water quality data. To calculate the organic loads from the algae, it was assumed that the nitrogen to chlorophyll *a* ratio was 12.5, and the phosphorus to chlorophyll *a* ratio was 1.25. This analysis was then repeated for the reduced nutrient loading conditions. The percentage difference between the amount of nutrients that settled in the expected condition scenarios and the amount that settled in the reduced loading scenarios was then applied to the nutrient fluxes in each segment. The reduced nutrient scenarios were then run again with the updated fluxes. A new value of settled organics was calculated, and new fluxes were calculated. The process was repeated several times, until the reduced fluxes remained constant.

- Along with reductions in nutrient fluxes from the sediments, when the nutrient loads to the system are reduced, the sediment oxygen demand will also be reduced (US EPA, 1997). It was assumed that the SOD would be reduced in the same proportion as the nitrogen fluxes, to a minimum of 0.3 $gO_2/m^2\ day$.

Scenario Results

Baseline Condition Scenarios:

First Scenario (Low Flow): Simulates the summer low flow expected conditions when water quality is impaired by high chlorophyll *a* levels, and low dissolved oxygen concentrations. Nonpoint source loads and water quality parameters are the same used in the low flow calibration and are based on 1998 observed data. Point source loads were based on the maximum allowable effluent limits as described above in the Point Source Loadings section. The results for this first scenario can be seen in Figures A26-A33. As shown in the figures, the peak chlorophyll *a* level is around the value of 110 µg/l, which is well above the management goal of 50 µg/l. The dissolved oxygen level is above the water quality standard of 5.0 mg/l throughout the water body system.

Second Scenario (Average Annual Flow): Simulates average stream flow conditions, with average annual nonpoint source loads estimated on the basis of 1997 land use, and projected year-2000 nutrient loading rates from the EPA Chesapeake Bay watershed model. Point source loads are the same used in the first scenario. This scenario does not show any violation of the standards, consequently no average annual TMDL is being established as a result of this analysis. The results for the second scenario can be seen in Figures A34-A41.

The MCEM calculates the daily average dissolved oxygen concentrations in the stream. This is not necessarily protective of water quality when one considers the effects of diurnal dissolved oxygen variation due to photosynthesis and respiration of algae. The photosynthetic process centers about the chlorophyll containing algae, which utilize radiant energy from the sun to convert water and carbon dioxide into glucose, and release oxygen. Because the photosynthetic process is dependent on solar radiant energy, the production of oxygen proceeds only during daylight hours. Concurrently with this production, however, the algae require oxygen for respiration, which can be considered to proceed continuously. Minimum values of dissolved oxygen usually occur in the early morning predawn hours when the algae have been without light for the longest period of time. Maximum values of dissolved oxygen usually occur in the early afternoon. The diurnal range (maximum minus minimum) may be large and if the daily mean level of dissolved oxygen is low, minimum values of dissolved oxygen during a day may approach zero and hence create a potential for fish kill. The diurnal dissolved oxygen variation due to photosynthesis and respiration is calculated by the MCEM based on the amount of chlorophyll *a* in the water. For the rest of the model results, the minimum dissolved oxygen concentration is reported.

Future Condition TMDL Scenarios:

Third Scenario (Low Flow): Simulates the future condition of maximum allowable loads for critical low stream flow conditions during summer season, as described above in the scenario descriptions section.

The results of the third scenario indicate that, under summer low flow conditions, the water quality target for dissolved oxygen and chlorophyll *a* is satisfied at all locations along the mainstem of the Marshyhope Creek. The results of the third Scenario are presented in Figures A42-A49.

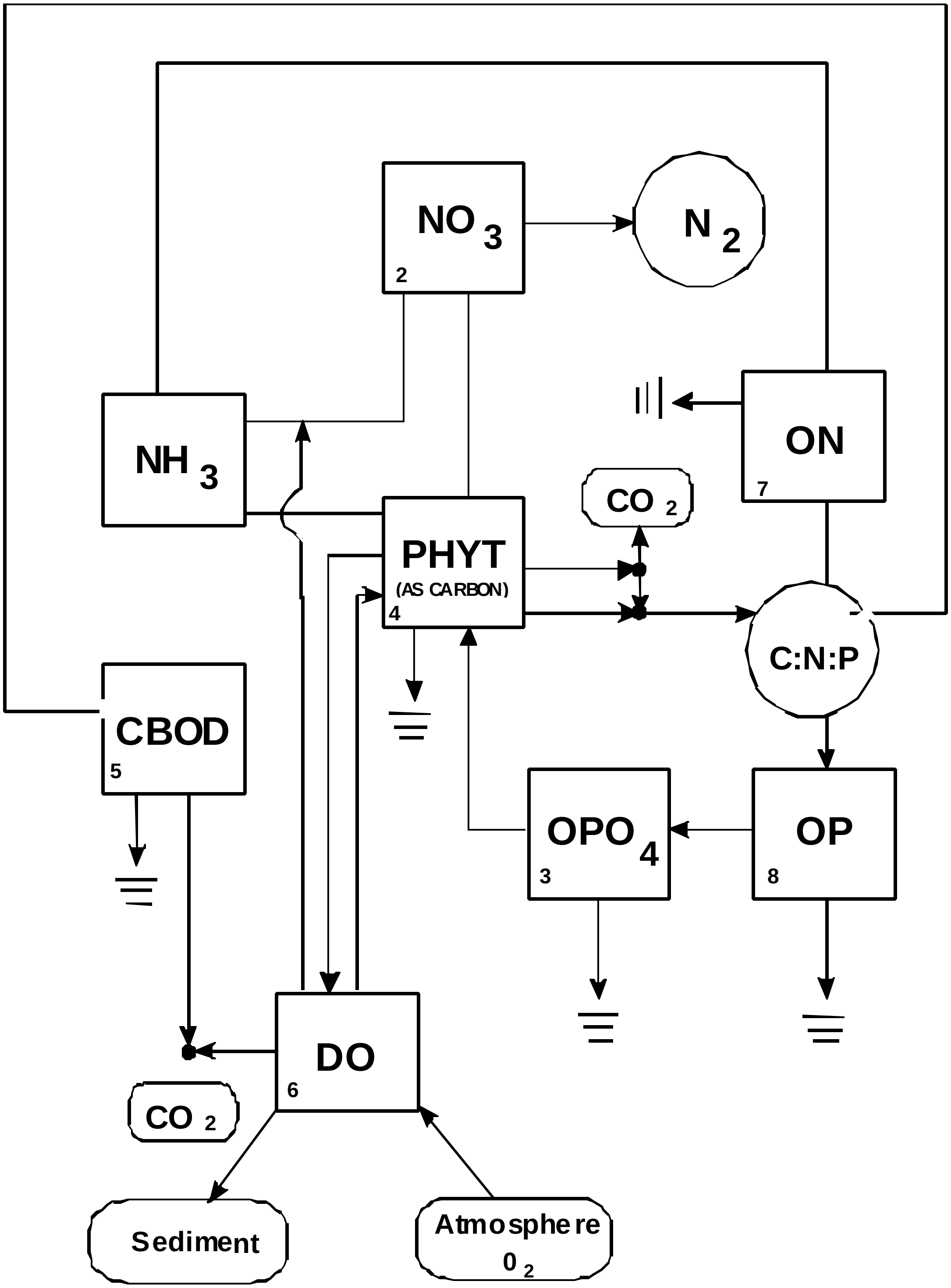


Figure A1: State Variables and Kinetic Interactions in EUTRO5

Table A1: Field and Laboratory Protocols

Parameter	Units	Detection Limits	Method Reference
IN SITU:			
Flow	cfs	0.01 cfs	Meter (Marsh-McBirney Model 2000 Flo-Mate)
Temperature	degrees Celsius	-5 deg. C to 50 deg. C	Linear thermistor network; Hydrolab Multiparameter Water Quality Monitoring Instruments Operating Manual (1995) Surveyor 3 or 4 (HMWQMIOM)
Dissolved Oxygen	mg/L	0 to 20 mg/l	Au/Ag polargraphic cell (Clark); HMWQMIOM
Conductivity	micro Siemens/cm (µS/cm)	0 to 100,000 µS/cm	Temperature-compensated, five electrode cell Surveyor 4; or six electrode Surveyor 3 (HMWQMIOM)
pH	pH units	0 to 14 units	Glass electrode and Ag/AgCl reference electrode pair; HMWQMIOM
Secchi Depth	meters	0.1 m	20.3 cm disk
GRAB SAMPLES:			
Ammonium	mg N / L	0.003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrate + Nitrite	mg N / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrite	mg N / L	0.0003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Nitrogen	mg N / L	0.03	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Nitrogen	mg N / L	0.0123	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Ortho-phosphate	mg P / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Phosphorus	mg P / L	0.0015	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Phosphorus	mg P / L		Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Phosphorus	mg P / L	0.0024	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Dissolved Organic Carbon	mg C / L	0.15	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Carbon	mg C / L	0.0759	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Silicate	mg Si / L	0.01	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Suspended Solids	mg / L	2.4	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Chlorophyll *a*	µg/L	1 mg/cu.M	Standard methods for the Examination of Water and Wastewater (15th ed.) #1002G. Chlorophyll. Pp 950-954
BOD_5	mg/l	0.01 mg/l	Oxidation ** EPA No. 405

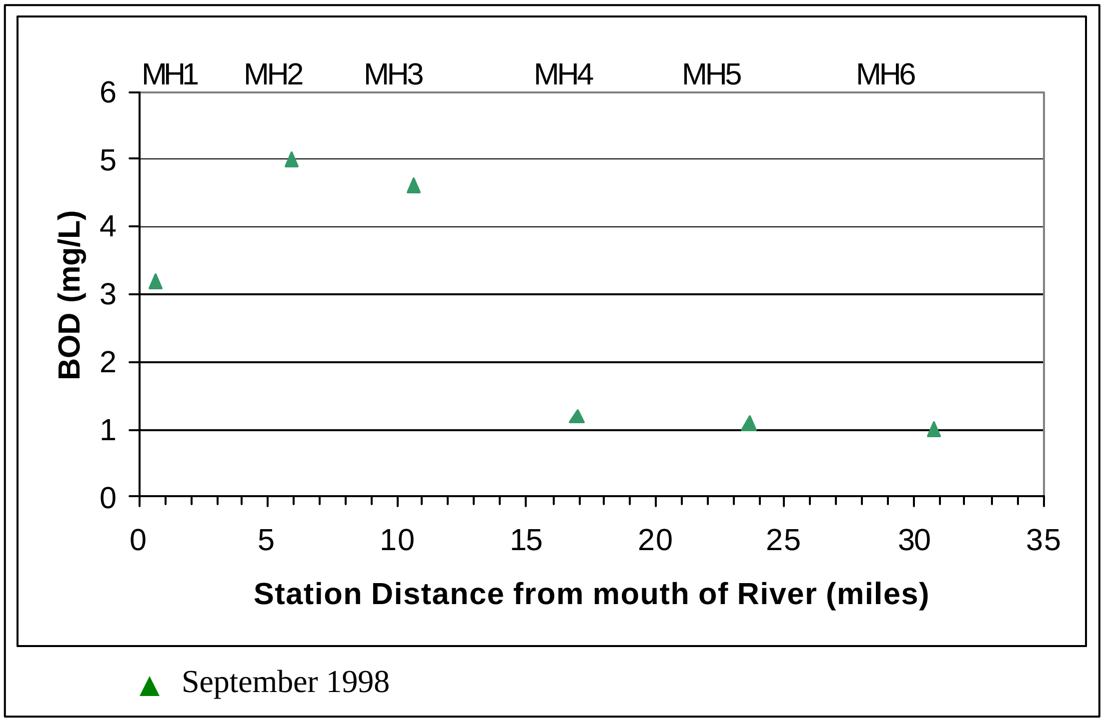


Figure A2: Longitudinal Profile of Biological Oxygen Demand Data

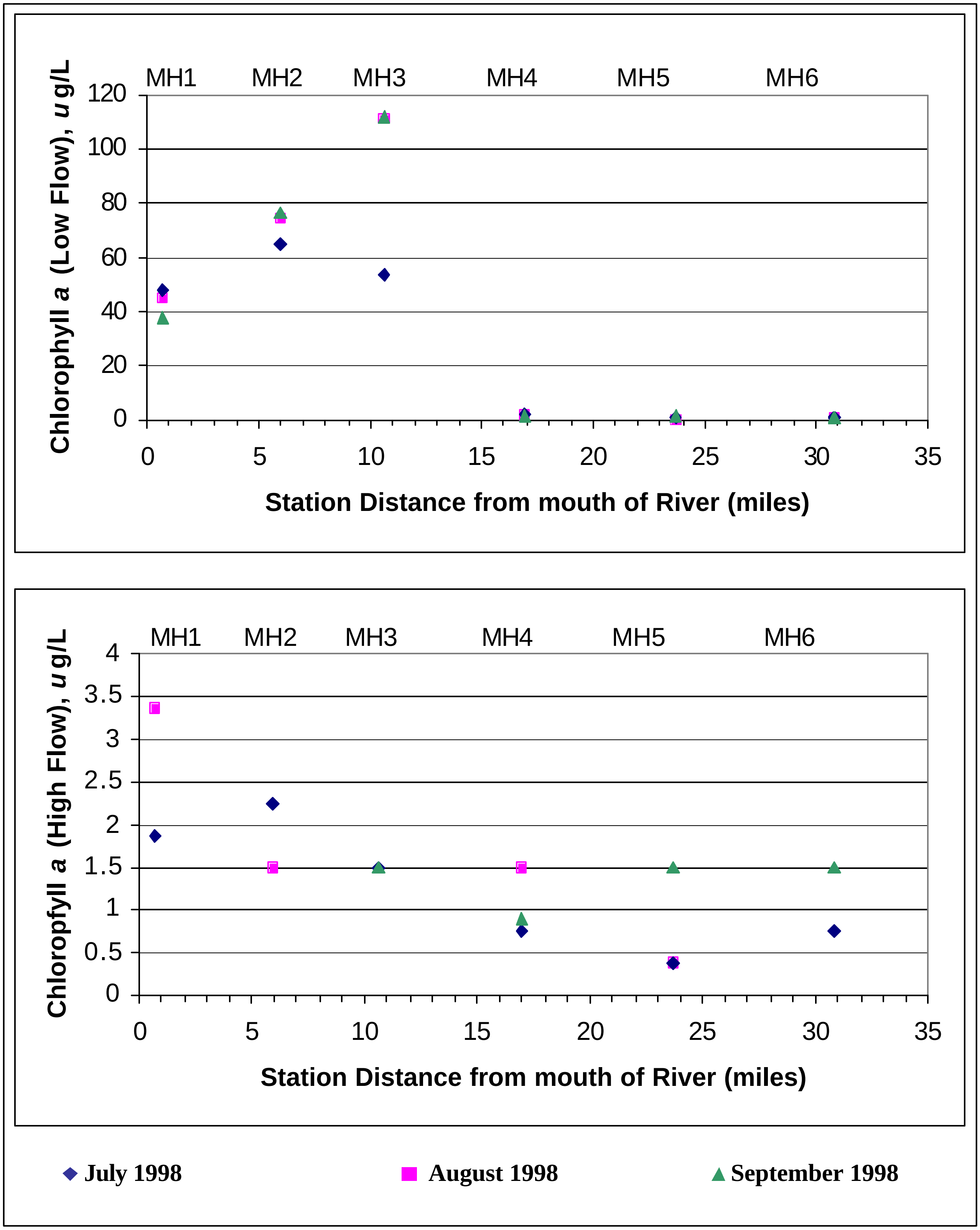


Figure A3: Longitudinal profile of Chlorophyll *a* data

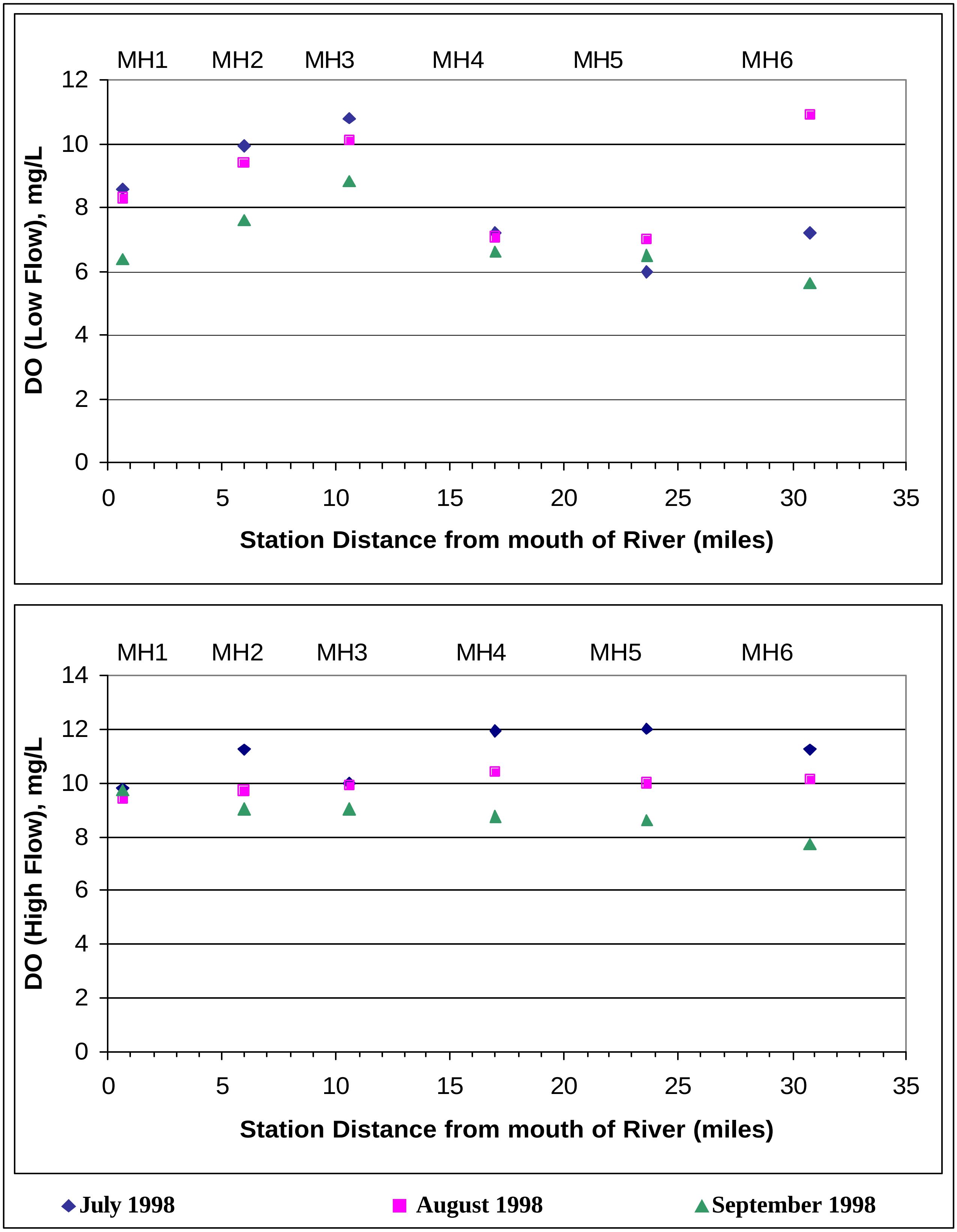


Figure A4: Longitudinal Profile of Dissolved Oxygen Data

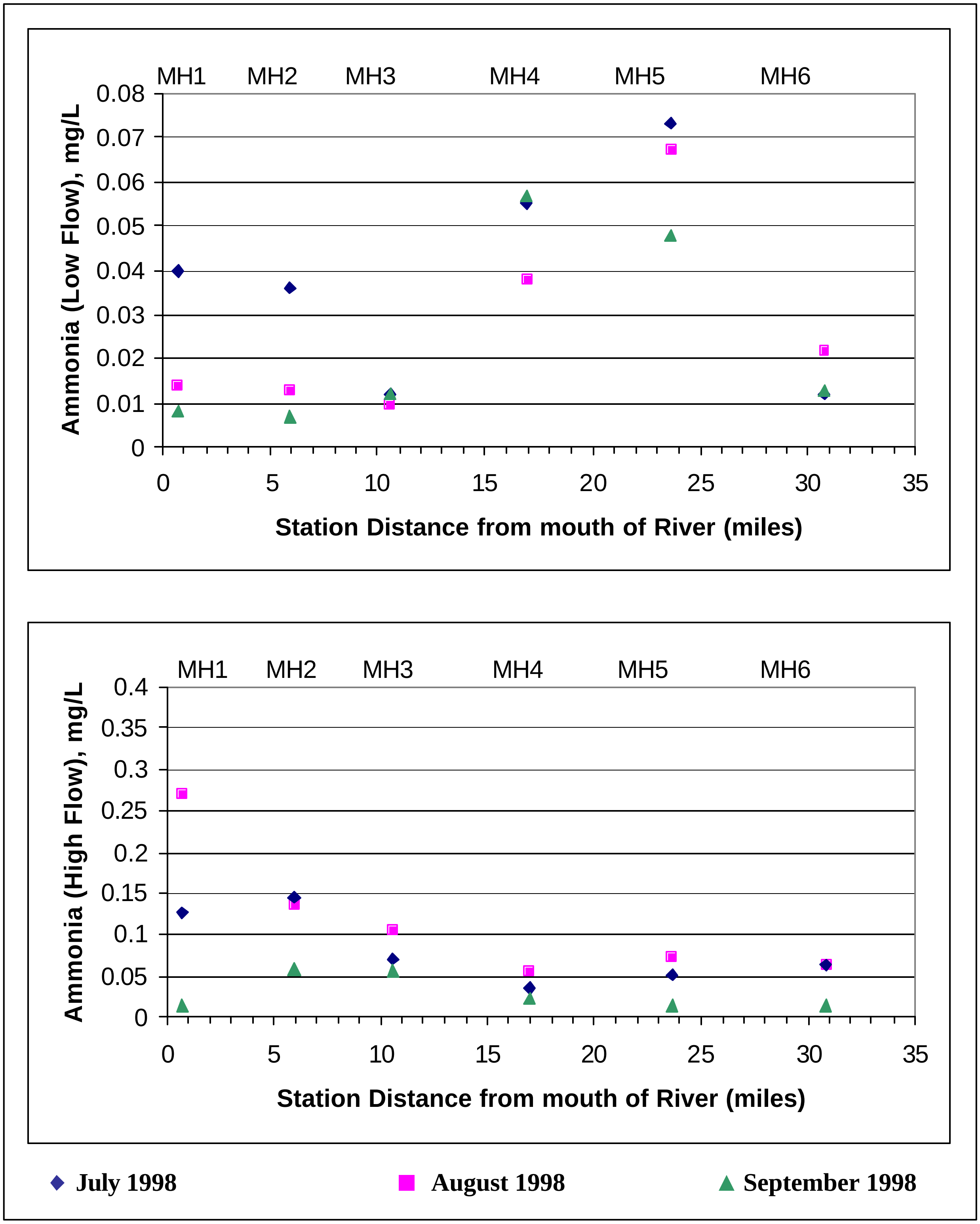


Figure A5: Longitudinal Profile of Ammonia Data

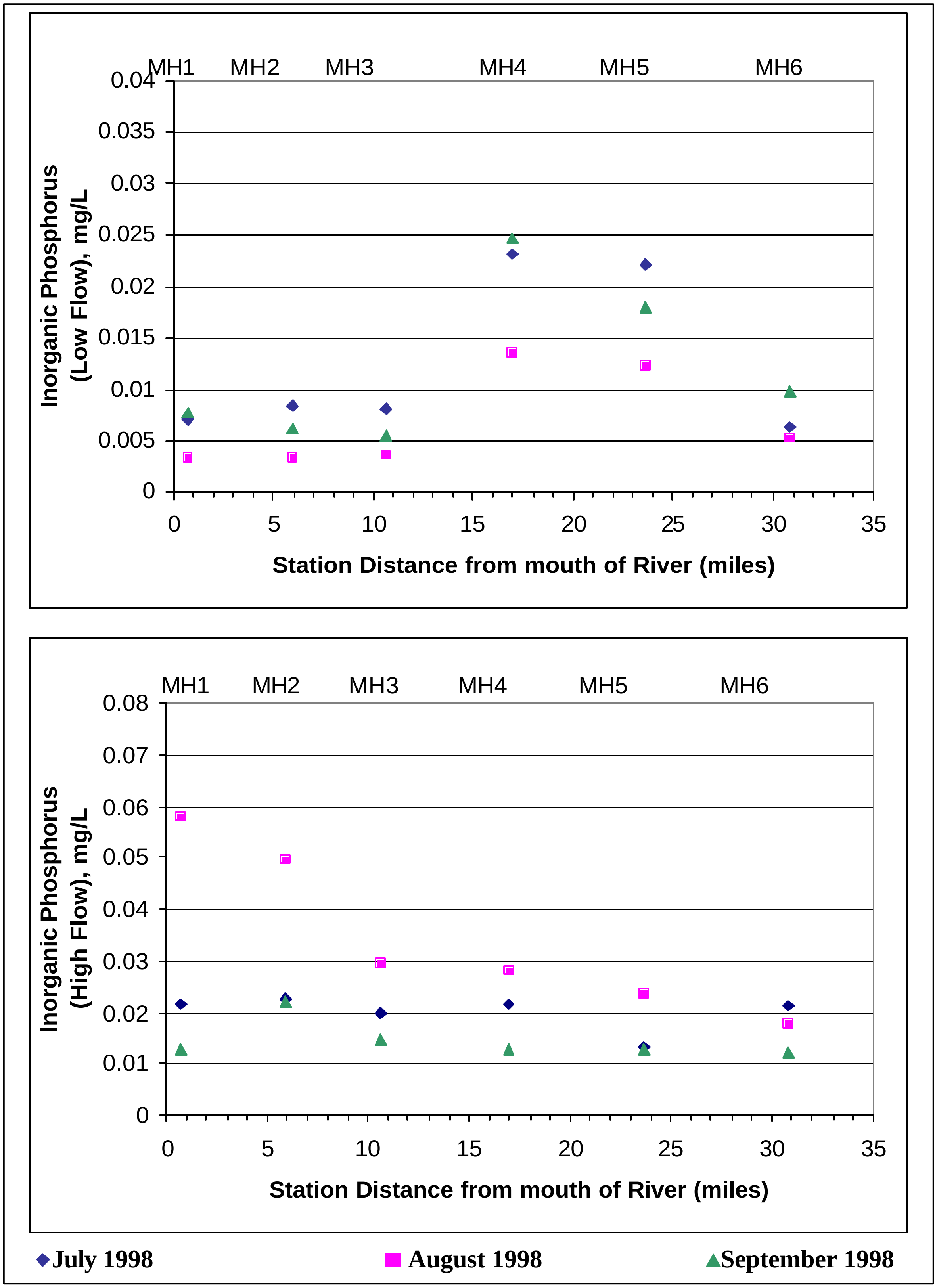


Figure A6: Longitudinal Profile of Inorganic Phosphorus Data

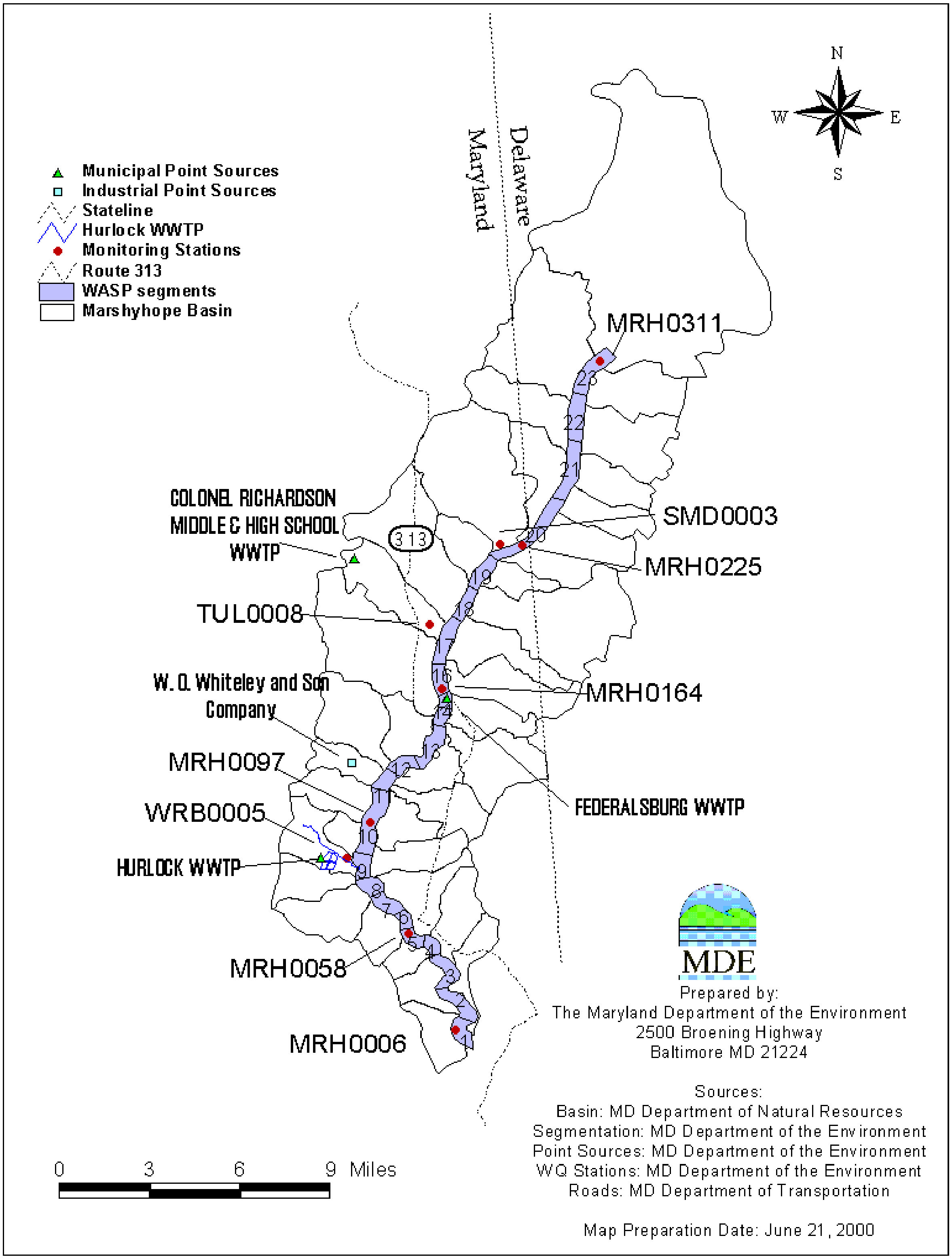


Figure A7: Model Segmentation, including Subwatersheds

Table A2: Volumes, Characteristic Lengths, Interfacial Areas used in the MCEM

Segment No.	Volume m^3	CharacteristicLength m	Interfacial Area m^2
1	1,040,800	1,220	881.25
2	2,264,643	2,070	834.99
3	2,240,136	3,025	724.25
4	645,277	2,015	707.50
5	1,295,280	1,360	726.45
6	617,884	1,370	694.05
7	921,750	1,295	642.70
8	630391	1,550	456.05
9	339,652	1,122.5	426.34
10	943,577	1,887.5	409.41
11	211,984	2,580	253.08
12	298,779	2,365	135.90
13	411,152	3,160	101.85
14	113,240	2,370	119.20
15	71,520	775	119.20
16	193,434	1,250	119.20
17	128,192	1,887.5	85.82
18	193,440	2,797.5	52.00
19	110,240	2,920	52.00
20	243,909	3,460	52.00
21	123,926	3,715	49.42
22	111,800	2,565	44.72
23	150,259	2,930	44.72

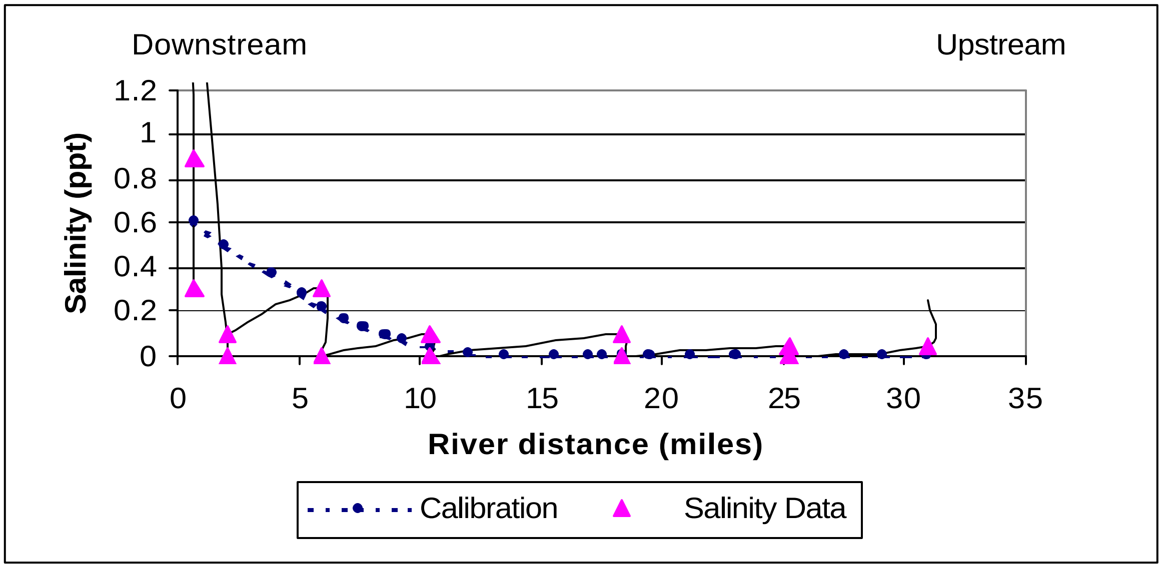
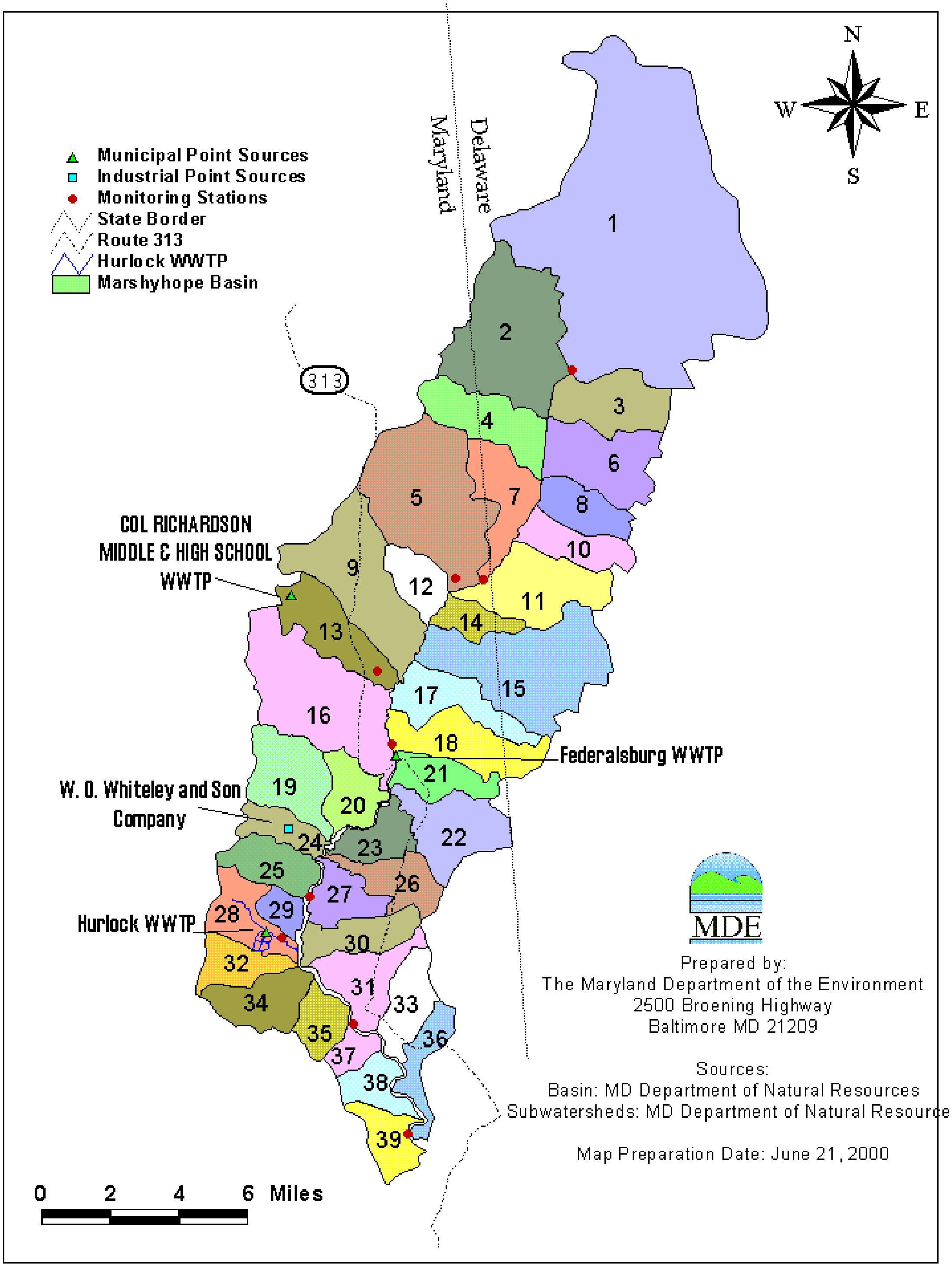


Figure A8: Results of the Calibration of Exchange Coefficients for Low Flow

Table A3: Dispersion Coefficients used in the MCEM

Segment Number	Dispersion Coefficient (m^2/sec)
Tidal Water Segments	
1	19
2	19
3	19
4	18
5	18
6	17
7	17
8	14
9	12
10	10
11	7
12	6
13	5
14	4
15	3
16	3
Free Flowing Water Segments	
17	0.0001
18	0.0001
19	0.0001
20	0.0001
21	0.0001
22	0.0001
23	0.0001



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Sources:
Basin: MD Department of Natural Resources
Subwatersheds: MD Department of Natural Resource

Map Preparation Date: June 21, 2000

Figure A9: The Thirty Nine Subwatersheds of the Marshyhope Creek Drainage Basin

Table A4: Subwatersheds Flow for Low, High, and Average Conditions

Subwatershed Number	Low Flow (m^3/s)	High Flow (m^3/s)	Average Flow (m^3/s)
1	0.414	2.780	1.270
2	0.109	0.731	0.334
3	0.047	0.315	0.144
4	0.047	0.318	0.145
5	0.118	0.791	0.361
6	0.057	0.381	0.174
7	0.041	0.276	0.126
8	0.029	0.195	0.089
9	0.086	0.578	0.264
10	0.030	0.202	0.092
11	0.059	0.397	0.181
12	0.024	0.162	0.074
13	0.046	0.308	0.141
14	0.018	0.118	0.054
15	0.106	0.709	0.324
16	0.108	0.729	0.333
17	0.040	0.267	0.122
18	0.050	0.333	0.152
19	0.048	0.326	0.149
20	0.028	0.190	0.087
21	0.028	0.187	0.085
22	0.050	0.333	0.152
23	0.025	0.169	0.077
24	0.021	0.138	0.063
25	0.031	0.208	0.095
26	0.031	0.206	0.094
27	0.026	0.177	0.081
28	0.034	0.227	0.104
29	0.013	0.085	0.039
30	0.031	0.207	0.095
31	0.038	0.257	0.117
32	0.025	0.170	0.078
33	0.031	0.210	0.096
34	0.036	0.240	0.110
35	0.022	0.146	0.067
36	0.023	0.158	0.072
37	0.013	0.085	0.039
38	0.022	0.147	0.067
39	0.025	0.166	0.076

Table A5: Point Source Loadings for the Calibration of Models

Parameter*		Hurlock	Federalsburg	Col. Richardson High School
Flow	**High Flow**	0.051	0.0175	0.00048
	Low Flow	0.00	0.0124	0.00048
NH4	**High Flow**	77.11	0.38	0.03
	Low Flow	0.00	0.32	0.025
NO_{23}	**High Flow**	4.41	21.98	0.72
	Low Flow	0.00	18.64	0.65
PO_4	**High Flow**	19.83	2.73	0.10
	Low Flow	0.00	0.82	0.095
Chl*a*	**High Flow**	7.70	0.00	0.00
	Low Flow	0.00	0.00	0.00
CBOD	**High Flow**	300.00	17.28	0.25
	Low Flow	0.00	10.16	0.23
DO	**High Flow**	51.33	14.48	0.32
	Low Flow	0.00	7.66	0.26
ON	**High Flow**	22.03	1.97	0.006
	Low Flow	0.00	2.04	0.005
OP	**High Flow**	6.61	0.46	0.02
	Low Flow	0.00	0.34	0.018

*** All loadings in kg/day. Flow in m^3/sec**

Table A6: Environmental Parameters for the Calibration of the Model

Segment	Ke (m^{-1})		T (°C)		Salinity (gm/L)		SOD (g O_2/m^2 day)		FNH_4 (mg NH_4-N/m^2 day)		FPO_4 (mg PO_4-P/m^2 day)	
Number	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow
1	3.0	3.30	7.9	26.0	0.0	0.609	0.5	0.5	4.0	80.0	1.5	18.0
2	3.0	3.30	7.9	26.0	0.0	0.497	0.5	0.5	4.0	80.0	1.5	18.0
3	3.0	3.30	7.9	26.0	0.0	0.373	0.5	0.5	4.0	80.0	1.5	18.0
4	3.0	3.30	7.9	26.0	0.0	0.277	0.5	0.5	4.0	80.0	1.5	18.0
5	3.0	3.30	7.9	26.0	0.0	0.213	0.5	0.5	4.0	80.0	1.5	18.0
6	3.0	3.30	7.9	26.0	0.0	0.171	0.5	0.5	4.0	80.0	1.5	18.0
7	3.0	3.30	7.9	26.0	0.0	0.139	0.5	0.5	4.0	75.0	1.5	16.0
8	3.0	3.30	6.2	24.7	0.0	0.099	0.5	0.5	4.0	75.0	1.5	16.0
9	3.0	3.30	6.2	24.7	0.0	0.067	0.5	0.5	4.0	60.0	1.5	14.0
10	3.0	3.30	6.2	24.7	0.0	0.038	0.5	0.5	4.0	60.0	1.5	14.0
11	3.0	3.30	6.2	24.7	0.0	0.016	0.5	0.5	0.0	50.0	0.0	8.0
12	3.0	3.30	6.2	24.7	0.0	0.003	0.5	0.5	0.0	30.0	0.0	4.0
13	3.0	3.30	6.2	24.7	0.0	0.0	0.5	0.5	0.0	20.0	0.0	2.0
14	3.0	3.30	6.2	24.7	0.0	0.0	0.5	0.5	0.0	20.0	0.0	1.0
15	3.0	10.00	6.2	24.7	0.0	0.0	0.5	0.5	0.0	15.0	0.0	0.4
16	3.0	10.00	6.2	24.7	0.0	0.0	0.2	0.2	0.0	15.0	0.0	0.4
17	2.50	14.00	6.2	24.7	0.0	0.0	0.2	0.2	0.0	15.0	0.0	0.4
18	2.50	14.00	6.2	24.7	0.0	0.0	0.2	0.2	0.0	12.0	0.0	0.3
19	2.50	19.50	6.4	20.8	0.0	0.0	0.2	0.2	0.0	4.0	0.0	0.12
20	2.50	19.50	6.4	20.8	0.0	0.0	0.2	0.2	0.0	3.0	0.0	0.08
21	2.50	19.50	6.4	20.8	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0
22	2.50	19.50	8.9	18.3	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0
23	2.50	19.50	8.9	18.3	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0

Table A7: EUTRO5 Kinetic Coefficients

Constant	Code	Value
Nitrification rate	K12C	0.09 *day* -1 at 20° C
temperature coefficient	K12T	1.08
Denitrification rate	K20C	0.09 *day* -1 at 20° C
temperature coefficient	K20T	1.08
Saturated growth rate of phytoplankton	K1C	2.0 *day* -1 at 20° C
temperature coefficient	K1T	1.08
Endogenous respiration rate	K1RC	0.05 *day* -1 at 20° C
temperature coefficient	K1RT	1.045
Nonpredatory phytoplankton death rate	K1D	0.04 *day* -1
Phytophankton Stoichometry		
Oxygen-to-carbon ratio	OCRB	2.67 $mg\ O_2 / mg\ C$
Carbon-to-chlorophyll ratio	CCHL	46
Nitrogen-to-carbon ratio	NCRB	0.25 *mg N/mg C*
Phosphorus-to-carbon ratio	PCRB	0.025 $mg\ PO_4\text{-}P/ mg\ C$
Half-saturation constants for phytoplankton growth		
Nitrogen	KMNG1	0.008 *mg* N / L
Phosphorus	KMPG1	0.002 *mg* P / P
Phytoplankton	KMPHY	0.0 *mg* C/ *L*
Grazing rate on phytoplankton	K1G	0.0 *L / cell-day*
Fraction of dead phytoplankton recycled to organic		
nitrogen	FON	0.5
phosphorus	FOP	0.5
Light Formulation Switch	LGHTS	1 = Smith
Saturation light intensity for phytoplankton	IS1	300. *Ly/day*
BOD deoxygenation rate	KDC	0.1 *day* -1 at 20° C
temperature coefficient	KDT	1.05
Half saturation const. for carb. deoxygenation	KBOD	0.5
Reaeration rate constant	K2	0.5 *day* -1 at 20° C
Mineralization rate of dissolved organic nitrogen	K71C	0.01 *day* -1
temperature coefficient	K71T	1.08
Mineralization rate of dissolved organic phosphorus	K58C	0.12 *day* -1
temperature coefficient	K58T	1.08
Phytoplankton settling velocity		0.069 *m/day*
Organics settling velocity		0.086 *m/day*

Table A8: Contributing Watersheds to Each Model Segment, and Flows for the Segments

Segment	Contributing Subwatersheds	Low Flow (m^3/s)	High Flow (m^3/s)	Average Flow (m^3/s)
1	39	0.025	0.166	0.079
2	1/5(36)+1/2(38)	0.016	0.105	0.050
3	4/5(36)+1/2(38)+33+1/3(37)	0.065	0.439	0.210
4	0	0.000	0.000	0.000
5	4/5(31)+2/3(37)+1/2(35)	0.050	0.336	0.160
6	0	0.000	0.000	0.000
7	1/2(35)+1/5(31)+34	0.054	0.365	0.174
8	32+1/2(30)	0.000	0.274	0.131
9	1/2(30)+28	0.015	0.332	0.158
10	29+1/2(27)+25	0.057	0.382	0.183
11	1/4(27)	0.007	0.044	0.021
12	2/3(23)+26+1/4(27)+19+24	0.103	0.828	0.395
13	20+1/3(23)+22	0.086	0.580	0.277
14	21	0.028	0.187	0.089
15	0	0.000	0.000	0.000
16	18+1/2(16)	0.104	0.698	0.333
17	1/2(16)+13	0.054	0.674	0.322
18	17+15+9	0.231	1.557	0.743
19	14+12	0.042	0.281	0.134
20	5+11+10	0.207	1.392	0.665
21	7+8	0.070	0.472	0.226
22	4+6	0.104	0.700	0.334
23	1+2+3	0.570	3.833	1.830

Table A9: Nonpoint Source Concentrations for the Calibration of the Model for Low Flow

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *mg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
1	0.02	0.2	0.0	35.0	3.0	8.5	1.0	0.03
2	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
3	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
5	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
7	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
8	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
9	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
10	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
11	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
12	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
13	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
14	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
15	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00
16	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
17	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
18	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
19	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
20	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
21	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
22	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
23	0.003	1.90	0.01	0.0	2.00	8.5	0.63	0.002

Table A10: Nonpoint Source Concentrations for the Calibration of the Model for High Flow

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *mg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
1	0.25	3.22	0.03	1.80	3.33	8.00	0.90	0.08
2	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
3	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
5	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
7	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
8	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
9	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
10	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
11	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
12	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
13	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
14	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
17	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
18	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
19	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
20	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
21	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
22	0.05	3.77	0.03	0.94	3.33	11.15	0.32	0.03
23	0.064	2.64	0.02	0.75	3.33	10.65	0.32	0.04

Low Flow Calibration

Figure A10: BOD vs. River Mile for the Calibration of the Model (Low flow)

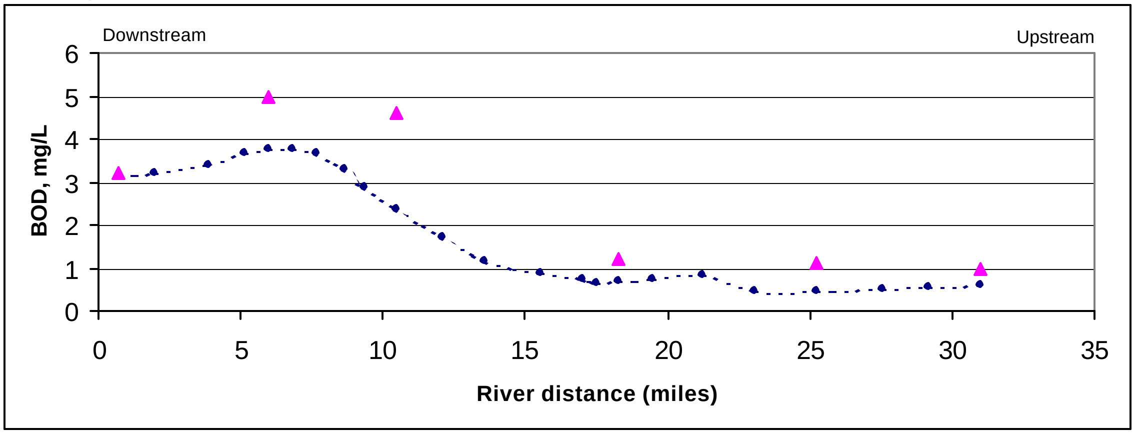


Figure A11: Dissolved Oxygen vs. River Mile for the Calibration of the Model (Low flow)

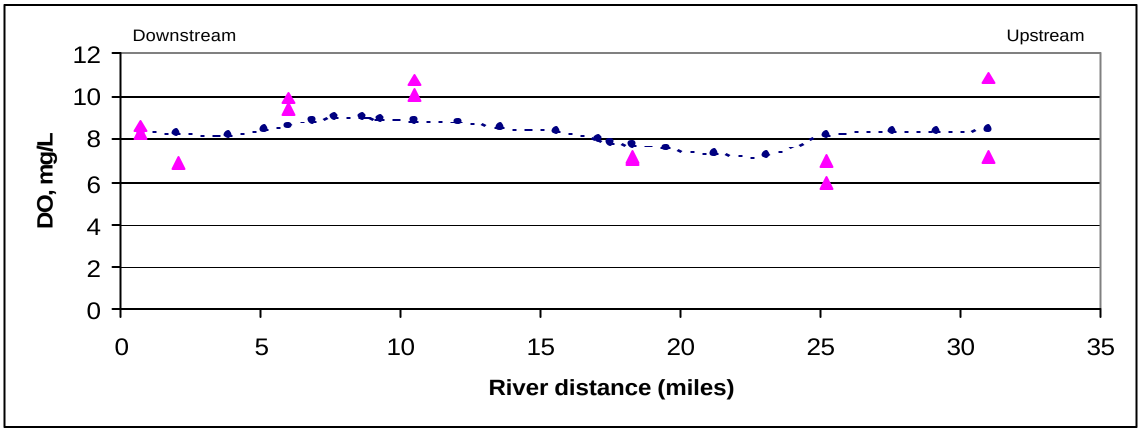
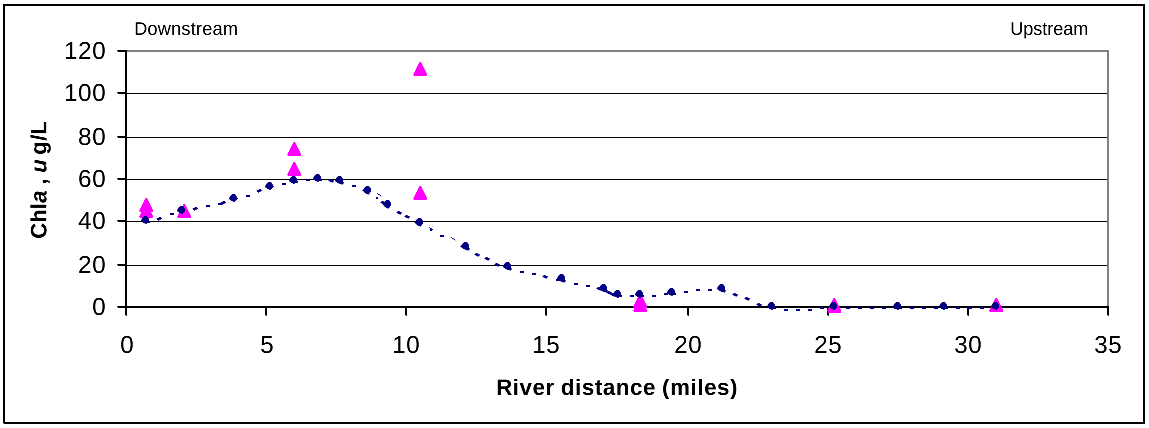


Figure A12: Chlorophyll *a* vs. River Mile for the Calibration of the Model (Low flow)



▲ **Monitoring Data** _________ **Calibration**

Figure A13: Nitrate (plus Nitrite) vs. River Mile for the Calibration of the Model (Low flow)

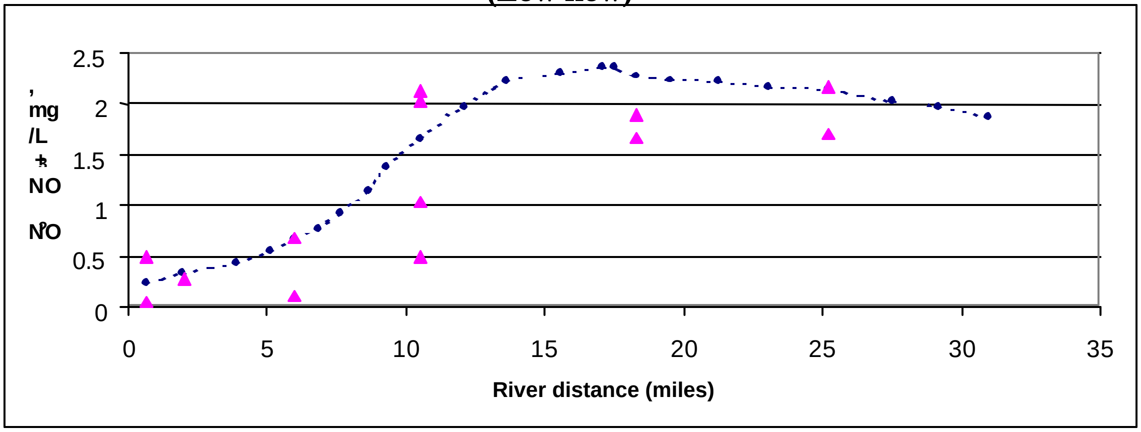


Figure A14: Organic Nitrogen vs. River Mile for the Calibration of the Model (Low flow)

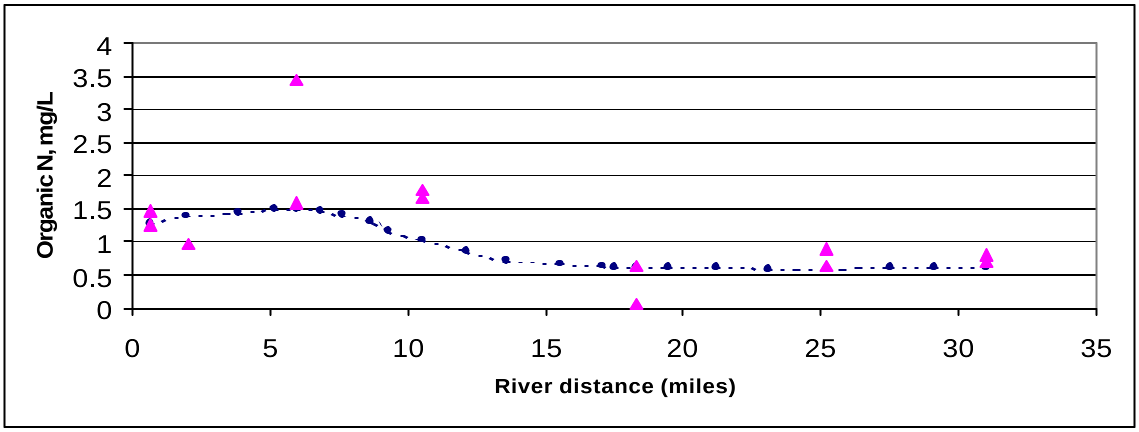
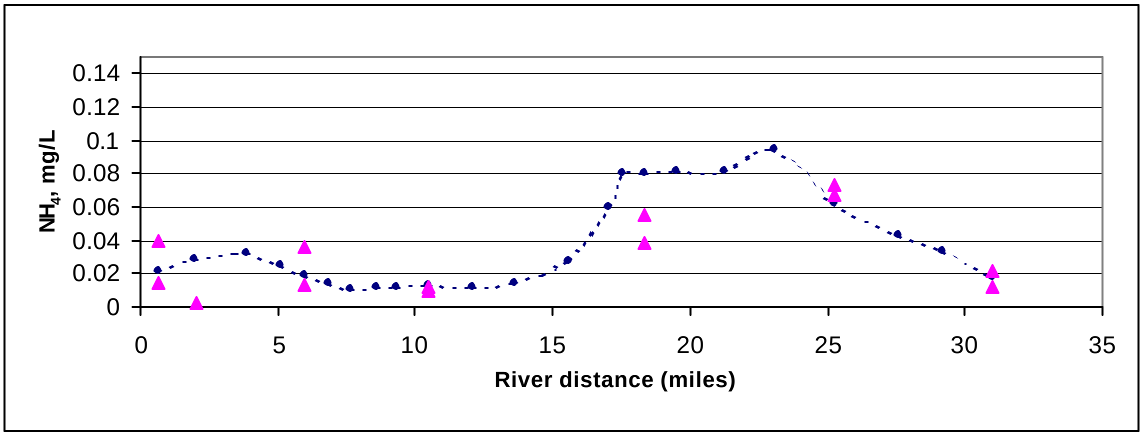


Figure A15: Ammonia vs. River Mile for the Calibration of the Model (Low flow)



▲ **Monitoring Data** ---------**Calibration**

Figure A16: Organic Phosphorus vs. River Mile for the Calibration of the Model (Low flow)

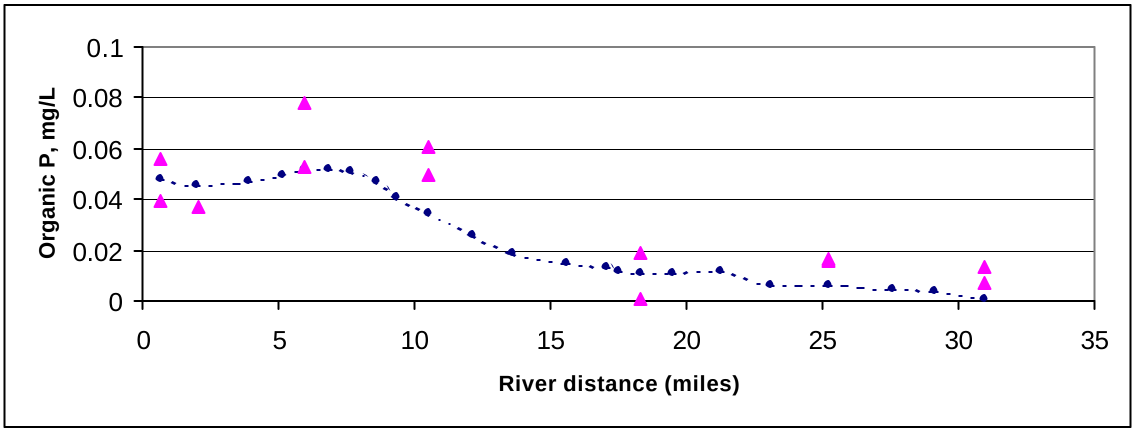
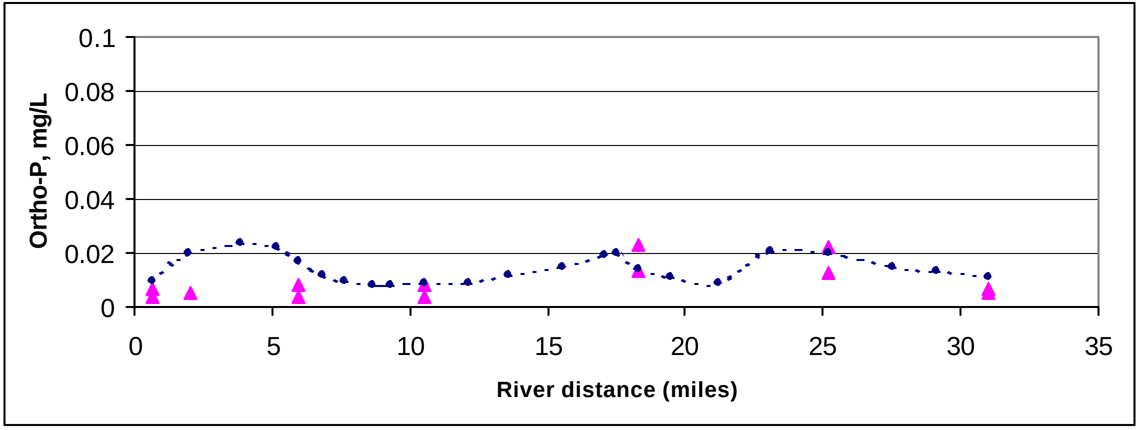


Figure A17: Ortho-Phosphate vs. River Mile for the Calibration of the Model (Low flow)



▲ **Monitoring Data** --------------- **Calibration**

High Flow Calibration

Figure A18: BOD vs. River Mile for the Calibration of the Model (High flow)

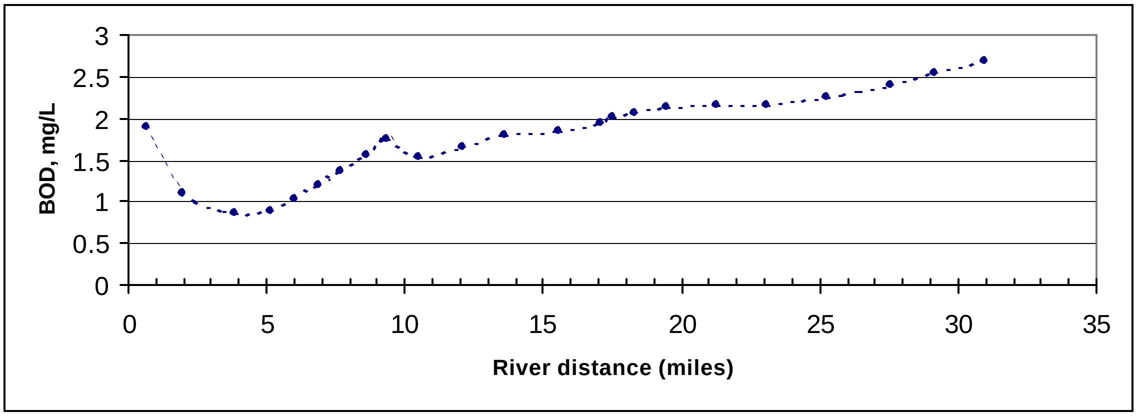


Figure A19: Dissolved Oxygen vs. River Mile for the Calibration of the Model (High Flow)

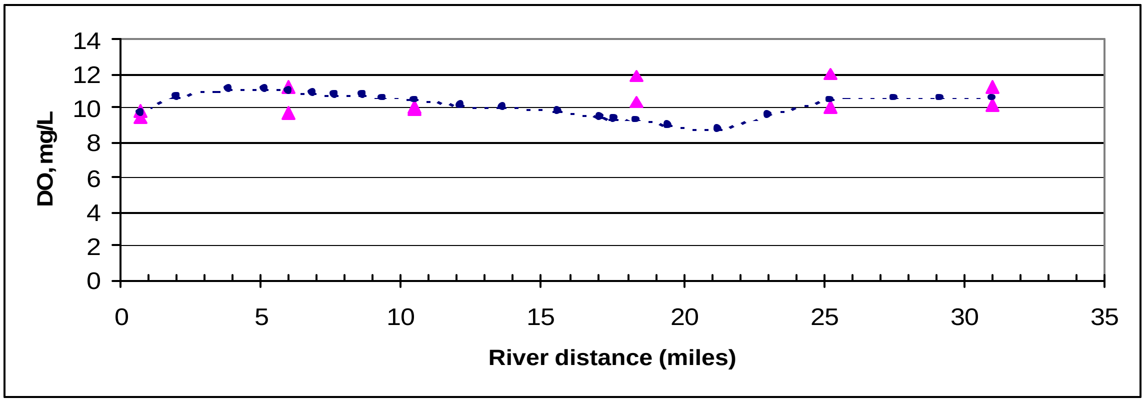
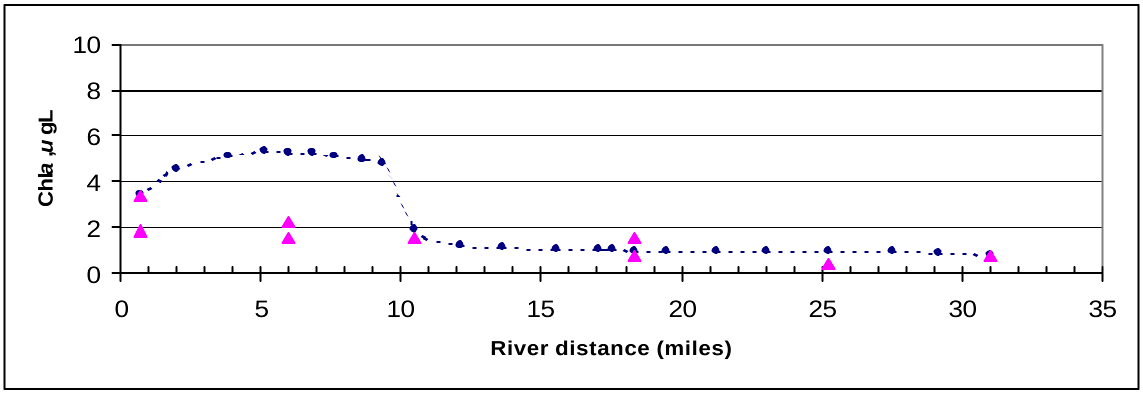


Figure A20: Chlorophyll *a* vs. River Mile for the Calibration of the Model (High flow)



▲ **Monitoring Data** ---------- **Calibration**

Figure A21: Nitrate (plus Nitrite) vs. River Mile for the Calibration of the Model (High flow)

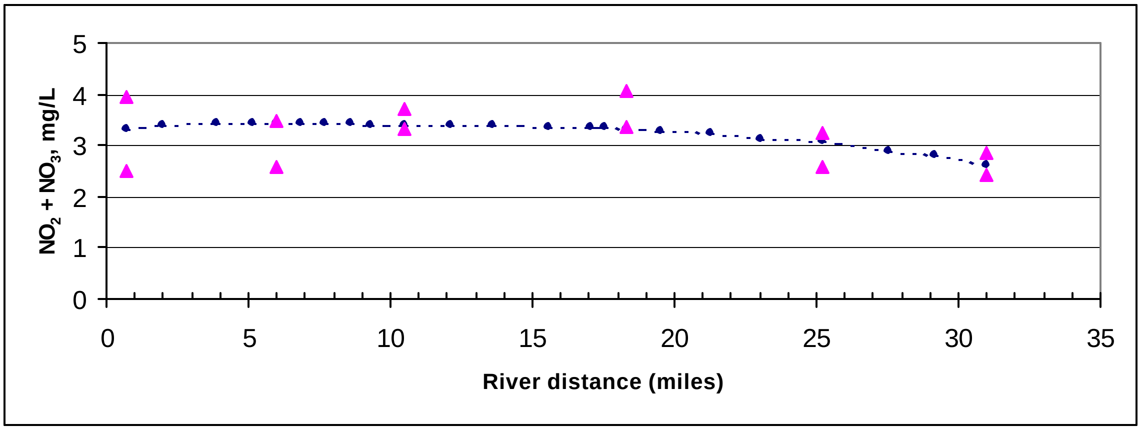


Figure A22: Organic Nitrogen vs. River Mile for the Calibration of the Model (High flow)

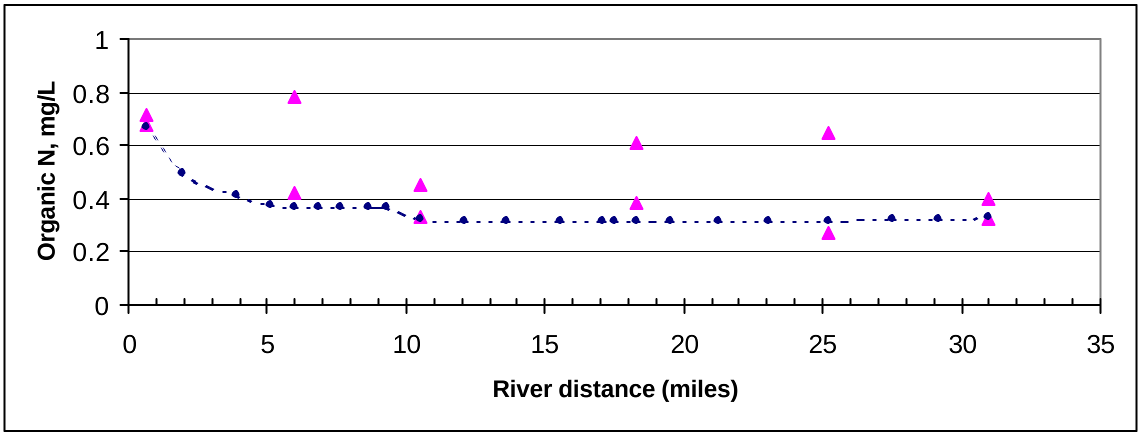
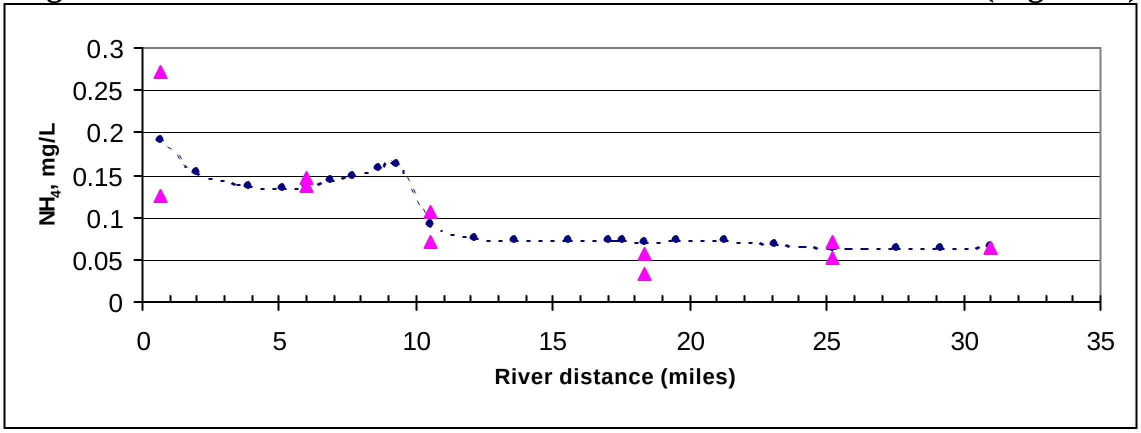


Figure A23: Ammonia vs. River Mile for the Calibration of the Model (High flow)



▲ **Monitoring Data** ‒ ‒ ‒ ‒ ‒ ‒ **Calibration**

Figure A24: Organic Phosphorus vs. River Mile for the Calibration of the Model (High flow)

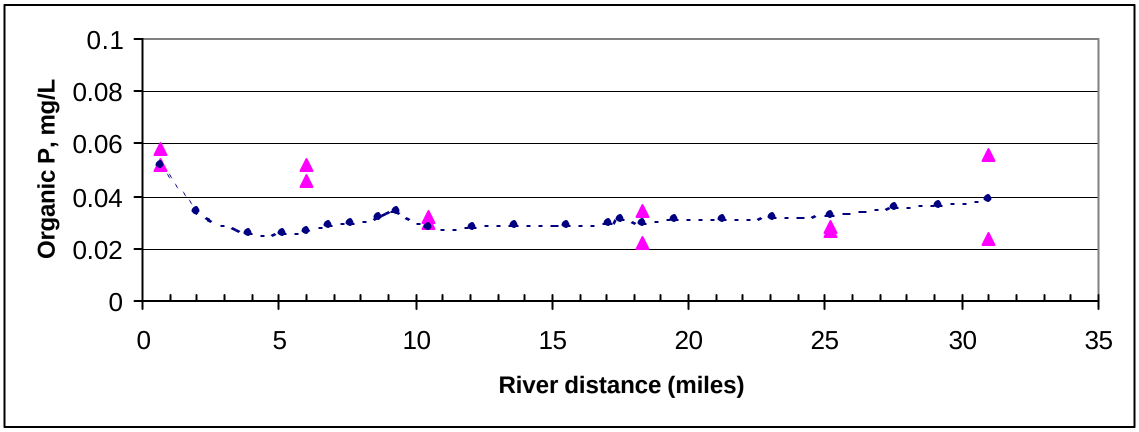
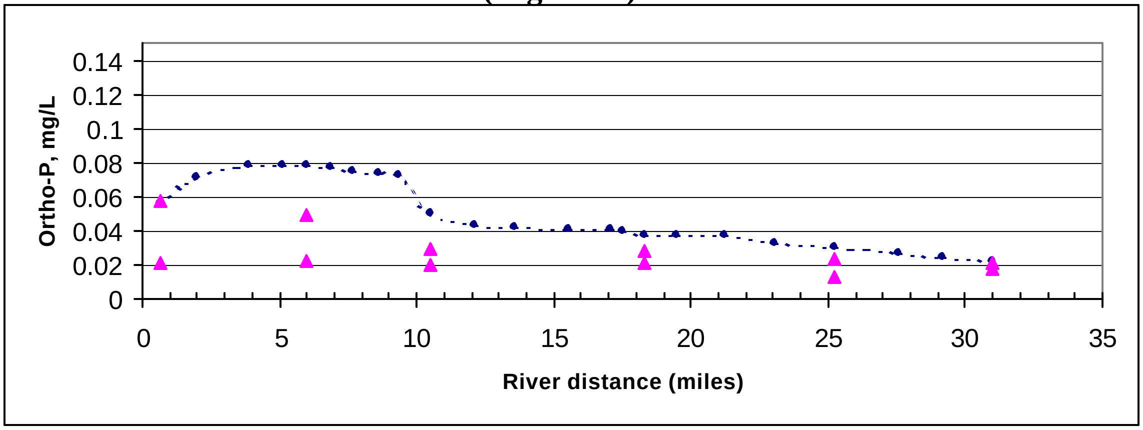


Figure A25: Ortho-Phosphate vs. River Mile for the Calibration of the Model (High flow)



▲ **Monitoring Data** ------------ **Calibration**

Table A11: Nonpoint Source Concentrations for the Low Flow Baseline Conditions Scenario

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *mg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
1	0.02	0.2	0.0	35.0	3.0	8.5	1.0	0.03
2	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
3	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
5	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
7	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
8	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
9	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
10	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
11	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
12	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
13	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
14	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
15	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00
16	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
17	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
18	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
19	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
20	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
21	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
22	0.075	2.65	0.023	1.16	2.08	7.0	0.82	0.024
23	0.003	1.90	0.01	0.0	2.00	8.5	0.63	0.002

Table A12: Point Source Loadings used in the Low Flow Baseline Conditions Scenario

Parameter*	Hurlock	Federalsburg	Col. Richardson High School
Flow	0.0657	0.0329	0.0005
NH_4	23.8	10.0	0.11
NO_{2-3}	3.8	95.8	1.1
PO_4	33.8	5.0	0.13
Chla	2.5	0	0
CBOD	160	95.0	0.22
DO	28.4	14.0	0.26
ON	10.0	18.0	0.02
OP	6.0	0.70	0.025

All loadings in kg/day. Flow in m^3/sec

Table A13: Nonpoint Source Concentrations for the Average Flow Baseline Conditions Scenario

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *mg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
1	0.13	1.18	0.07	25.00	5.00	8.50	0.49	0.07
2	0.14	1.38	0.09	1.16	2.08	6.97	0.55	0.08
3	0.16	1.62	0.11	1.16	2.08	6.97	0.64	0.11
5	0.15	1.49	0.10	1.16	2.08	6.97	0.62	0.09
7	0.16	1.67	0.12	1.16	2.08	6.97	0.67	0.11
8	0.18	1.72	0.12	1.16	2.08	6.97	0.71	0.11
9	0.19	1.83	0.11	1.16	2.08	6.97	0.65	0.10
10	0.12	1.32	0.09	1.16	2.08	6.97	0.51	0.08
11	0.04	0.55	0.01	1.16	2.08	6.97	0.31	0.02
12	0.17	1.75	0.12	1.16	2.08	6.97	0.80	0.12
13	0.16	1.73	0.11	1.16	2.08	6.97	0.72	0.11
14	0.18	2.06	0.11	1.16	2.08	6.97	0.74	0.11
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.20	2.20	0.13	1.16	2.08	6.97	0.90	0.12
17	0.18	1.93	0.13	1.16	2.08	6.97	0.81	0.12
18	0.21	2.22	0.13	1.16	2.08	6.97	0.96	0.12
19	0.13	1.26	0.08	1.16	2.08	6.97	0.68	0.08
20	0.22	2.34	0.13	1.16	2.08	6.97	0.96	0.12
21	0.25	2.65	0.13	1.16	2.08	6.97	1.14	0.12
22	0.23	2.44	0.12	1.16	2.08	6.97	1.05	0.11
23	0.34	3.50	0.17	0.00	0.50	4.25	1.43	0.15

Baseline Conditions Low Flow Scenario

Figure A26: BOD vs. River Mile for the Baseline Conditions Low Flow Scenario

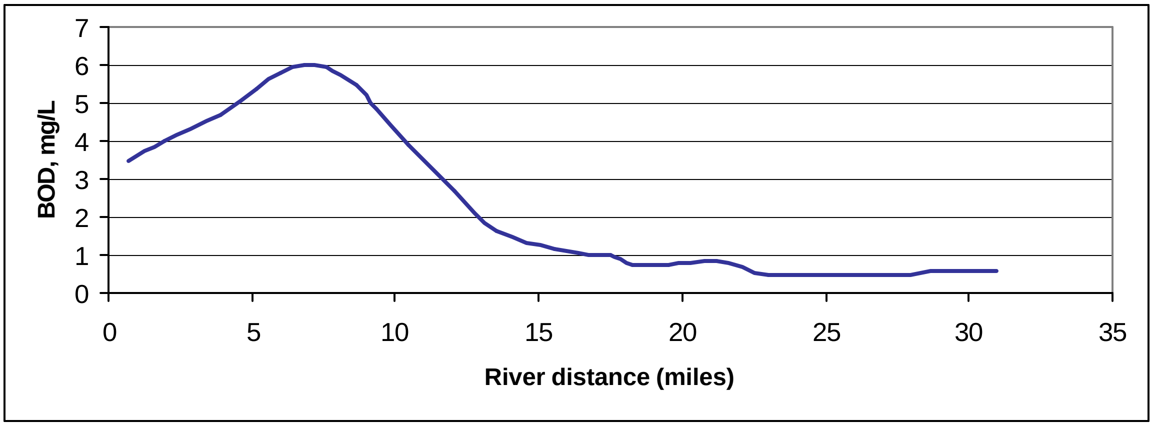


Figure A27: Dissolved Oxygen vs. River Mile for the Baseline Conditions Low Flow Scenario

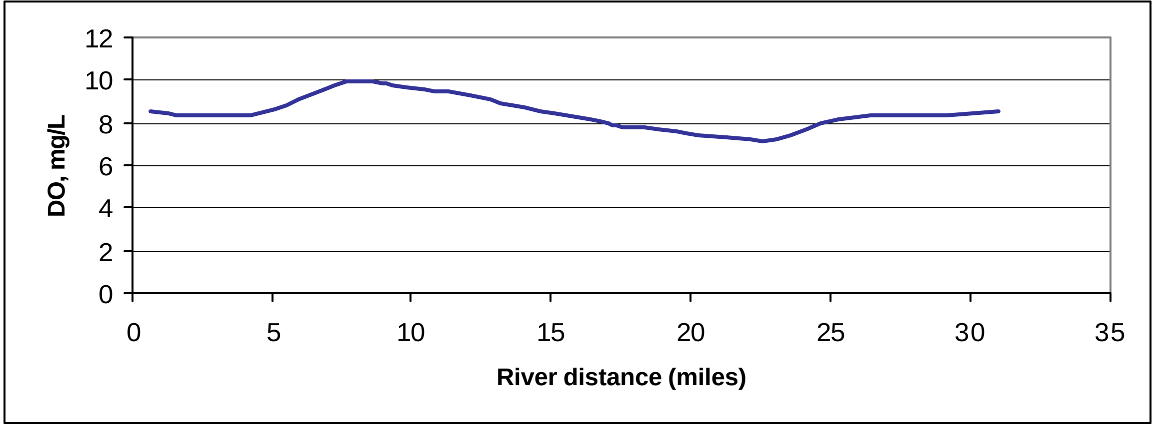
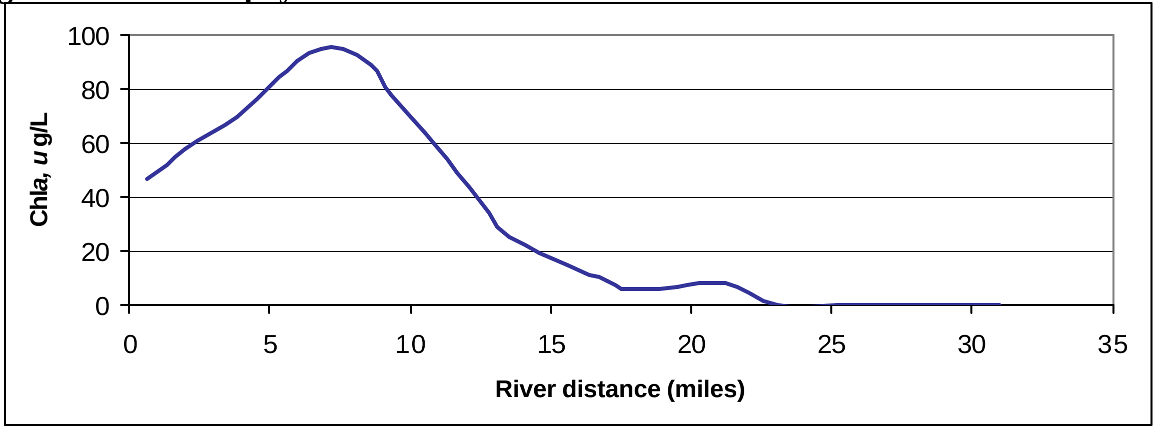


Figure A28: Chlorophyll *a* vs. River Mile for the Baseline Conditions Low Flow Scenario



▬ **Baseline Conditions low flow condition**

Figure A29: Nitrate (plus Nitrite) vs. River Mile for the Baseline Conditions Low Flow Scenario

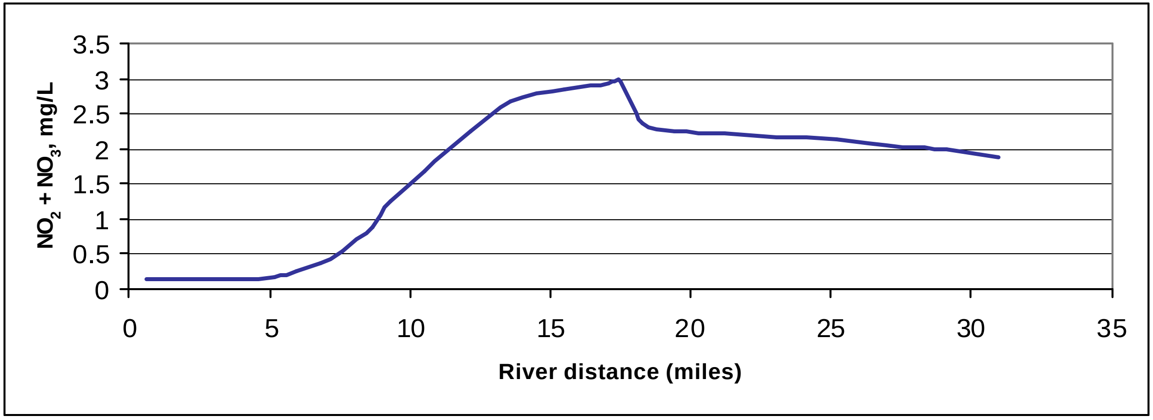


Figure A30: Organic Nitrogen vs. River Mile for the Baseline Conditions Low Flow

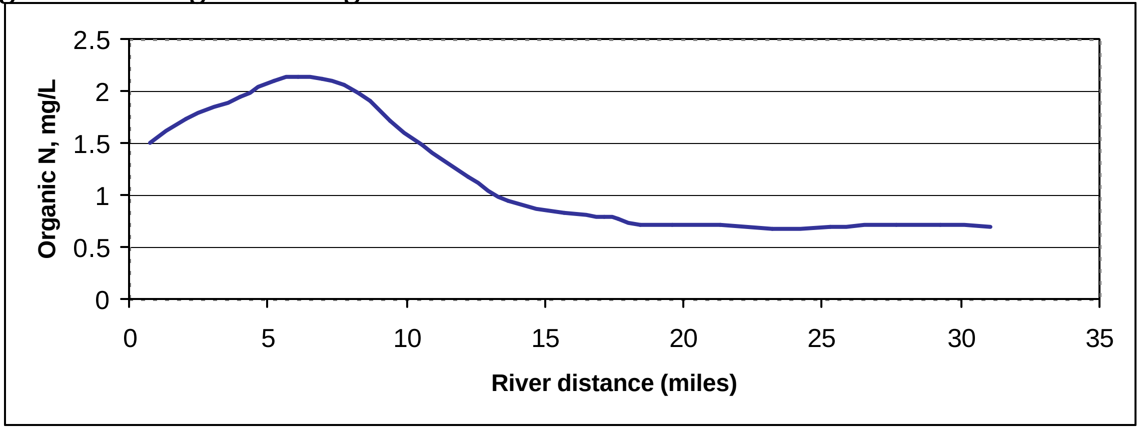
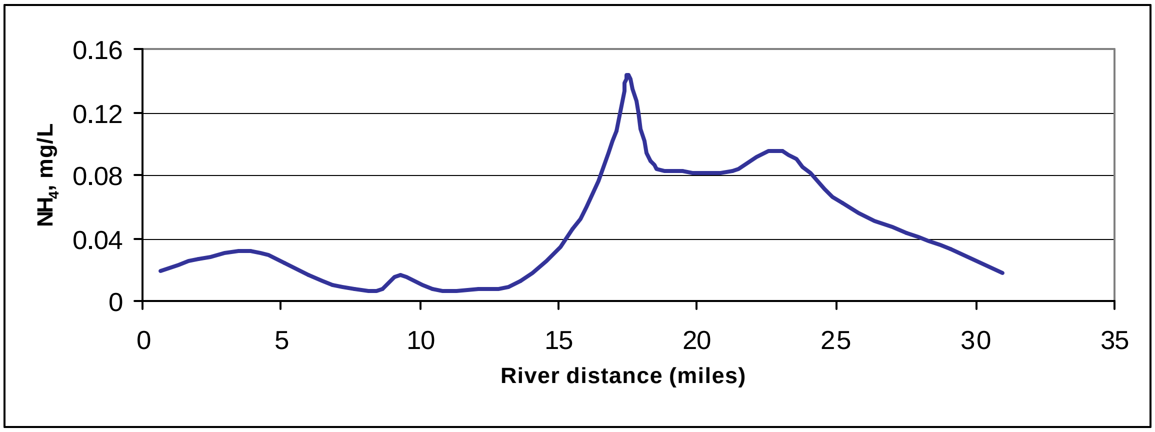


Figure A31: Ammonia vs. River Mile for the Baseline Conditions Low Flow Scenario



------------ **Low Flow Baseline Conditions**

Figure A32: Organic Phosphorus vs. River Mile for the Baseline Conditions Low Flow Scenario

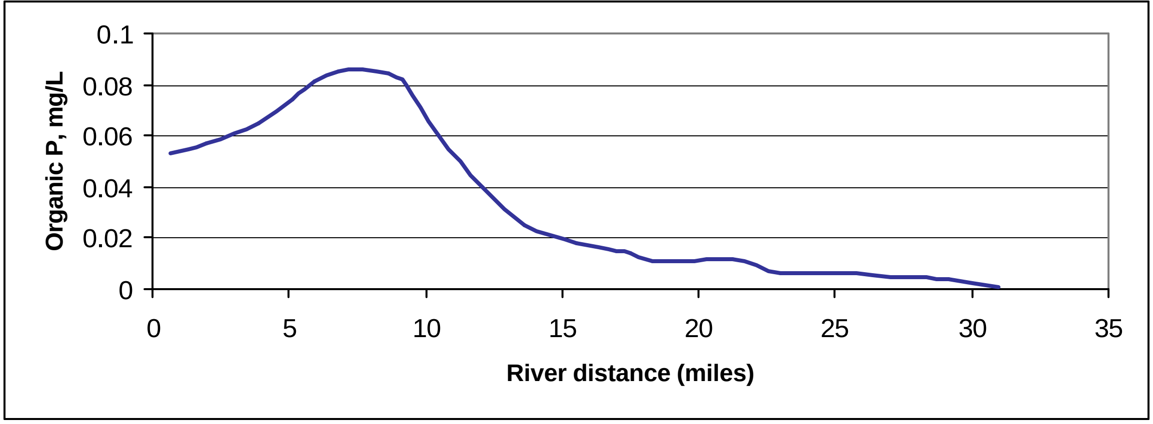
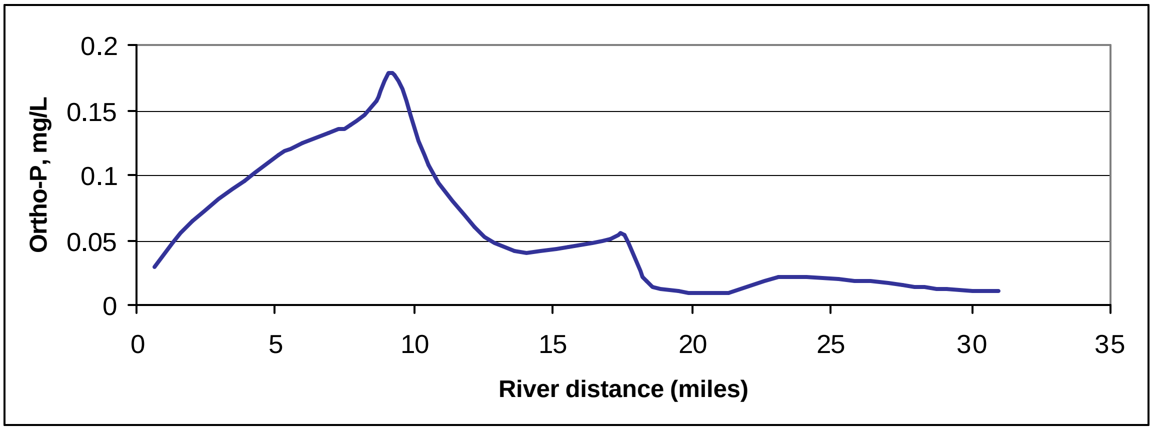


Figure A33: Ortho-Phosphorus vs. River Mile for the Baseline Conditions Low Flow Scenario



-------------- Low Flow Baseline Conditions

Baseline Conditions Average Flow Scenario

Figure A34: BOD vs. River Mile for the Baseline Conditions Average Flow Scenario

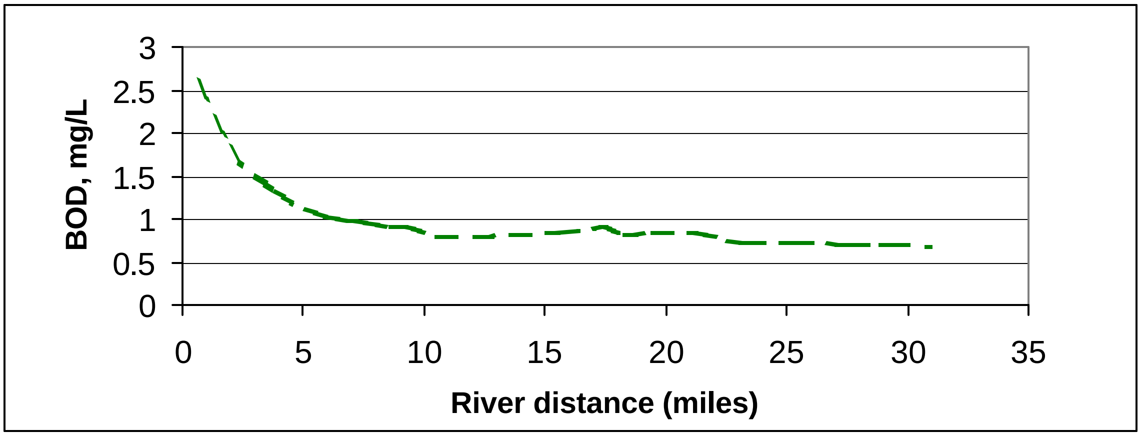


Figure A35: Dissolved Oxygen vs. River Mile for the Baseline Conditions Average Flow Scenario

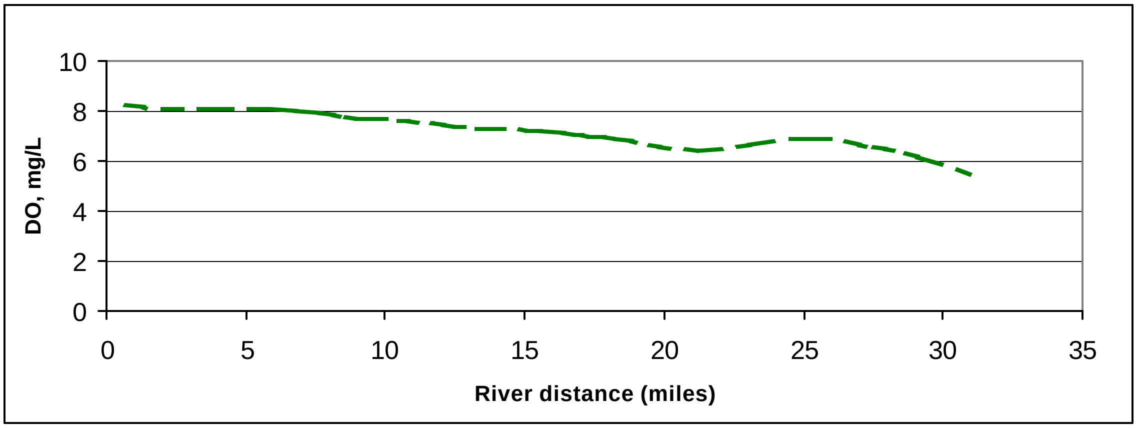
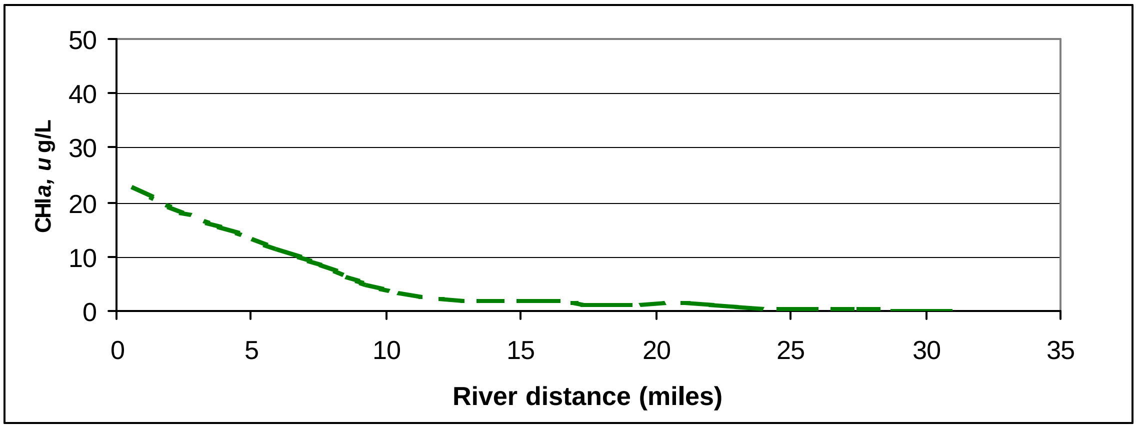


Figure A36: Chlorophyll *a* vs. River Mile for the Baseline Conditions Average Flow Scenario



– – – – – **Baseline Conditions Average Flow Scenario**

Figure A37: Nitrate (plus Nitrite) vs. River Mile for the Baseline Conditions Average Flow Scenario

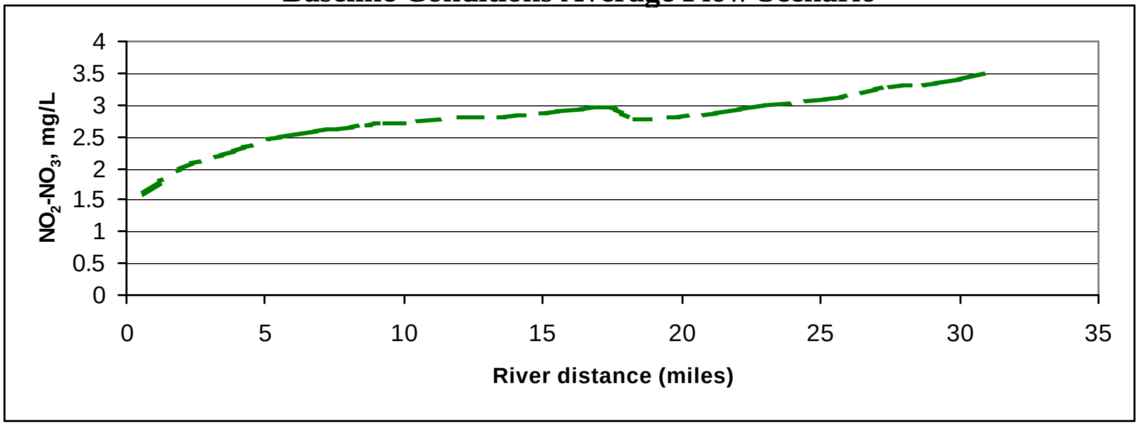


Figure A38: Organic Nitrogen vs. River Mile for the Baseline Conditions Average Flow Scenario

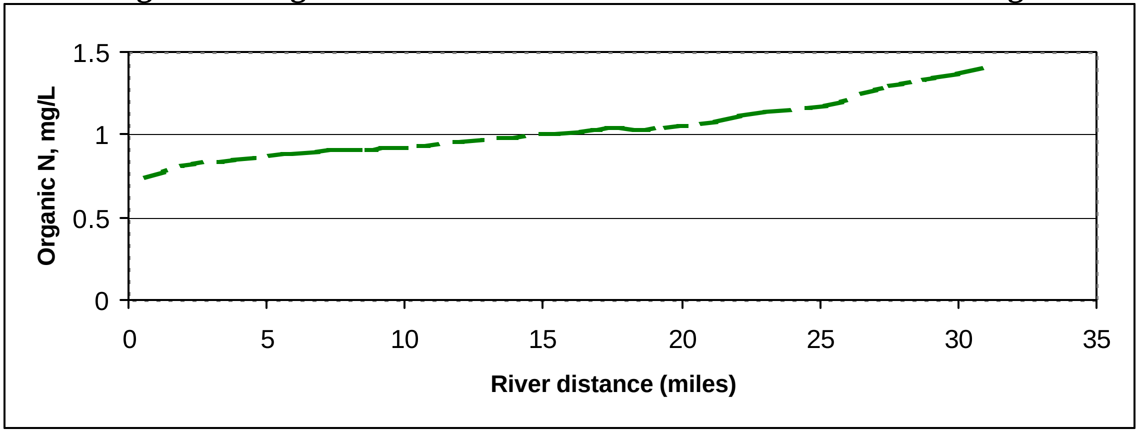
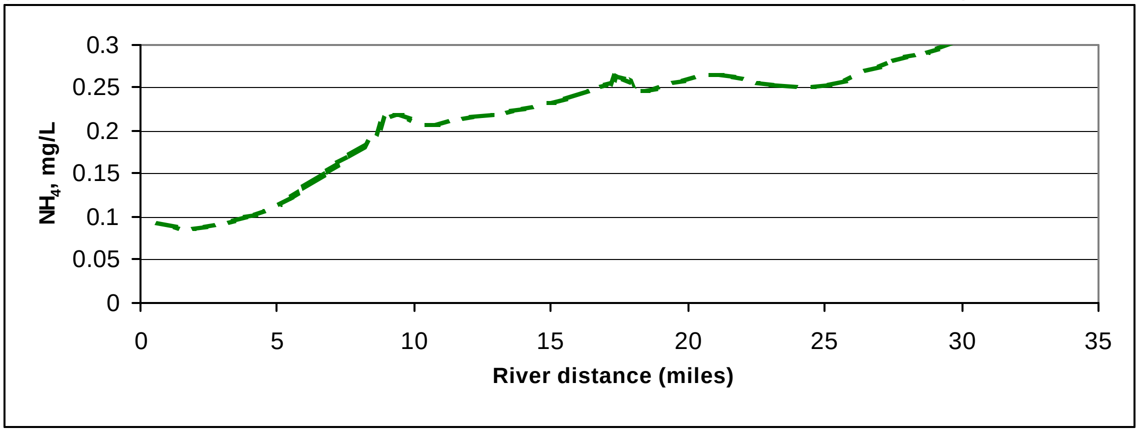


Figure A39: Ammonia vs. River Mile for the Baseline Conditions Average Flow Scenario



– – – – Baseline Conditions Average Flow Scenario

Figure A40: Organic Phosphorus vs. River Mile for the Baseline Conditions Average Flow Scenario

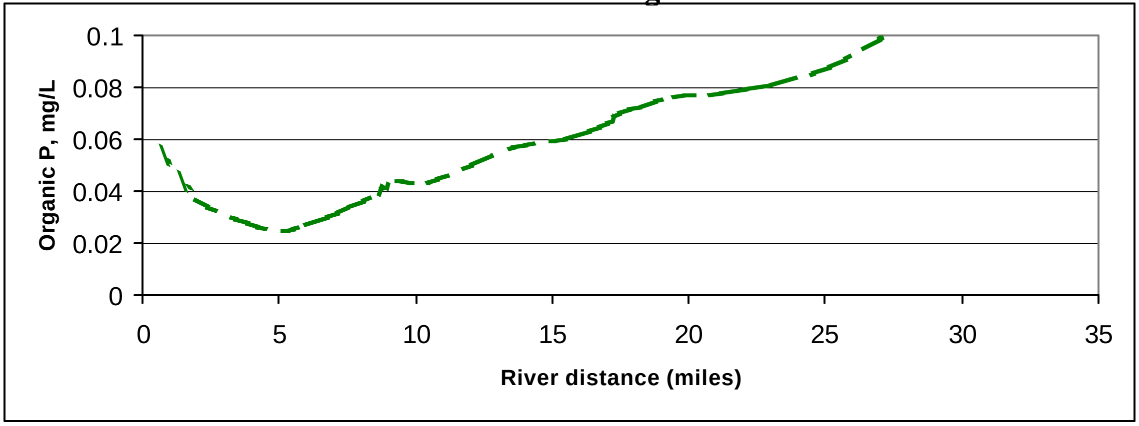
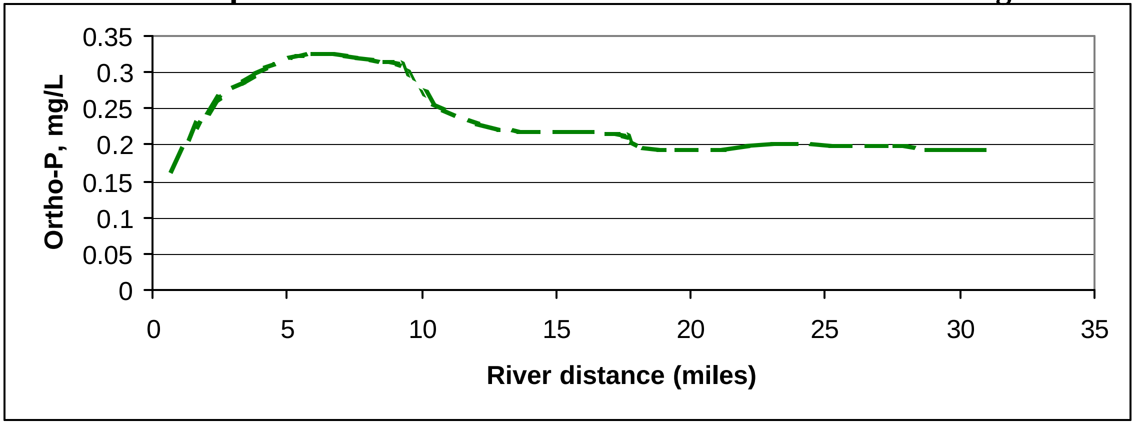


Figure A41: Ortho-Phosphorus vs. River Mile for the Baseline Conditions Average Flow Scenario



– – – – **Baseline Conditions Average Flow Scenario**

Future Low Flow TMDL Scenario Results

Figure A42: BOD vs. River Mile for the Future Low flow TMDL scenario

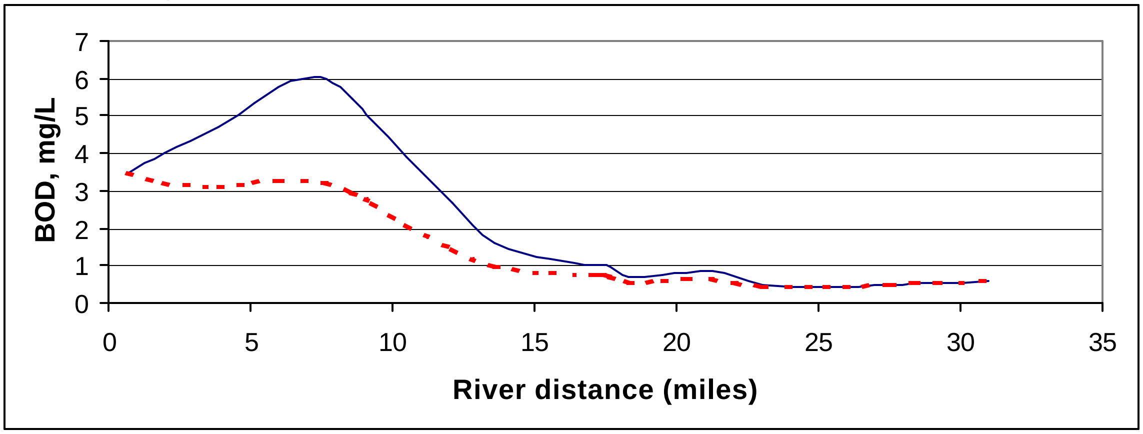


Figure A43: Dissolved Oxygen vs. River Mile for the Future Low Flow TMDL Scenario

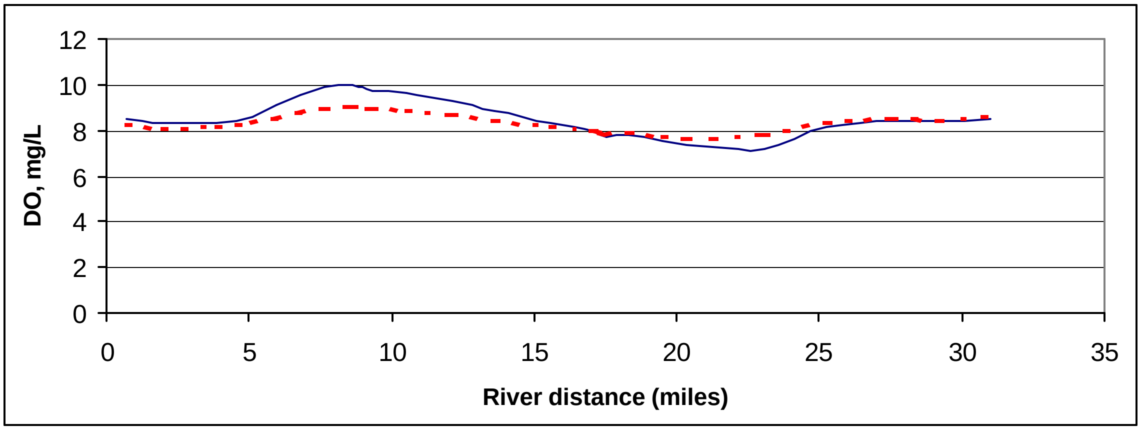
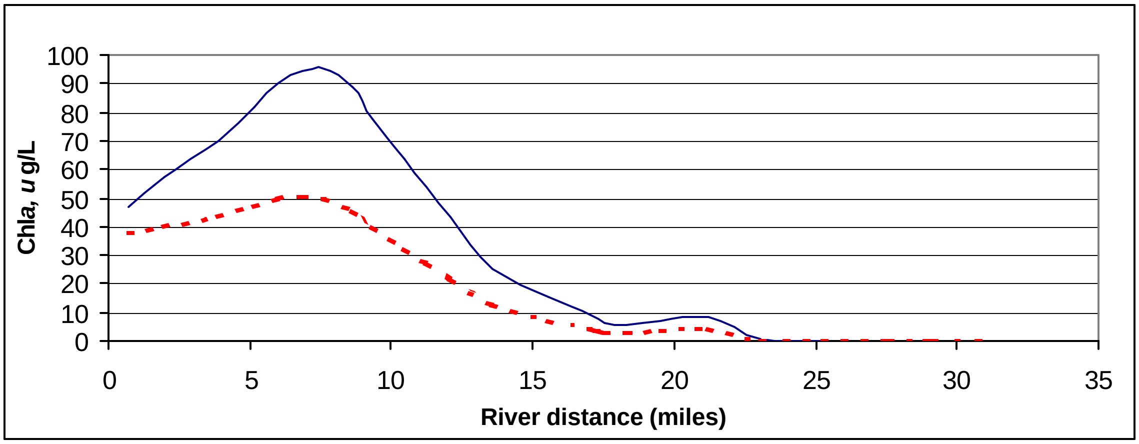


Figure A44: Chlorophyll *a* vs. River Mile for the Future Low Flow TMDL scenario



Baseline Conditions Low Flow Scenario **Future Low Flow TMDL Scenario**

Figure A45: Nitrate (plus Nitrite) vs. River Mile for the Future Low flow TMDL Scenario

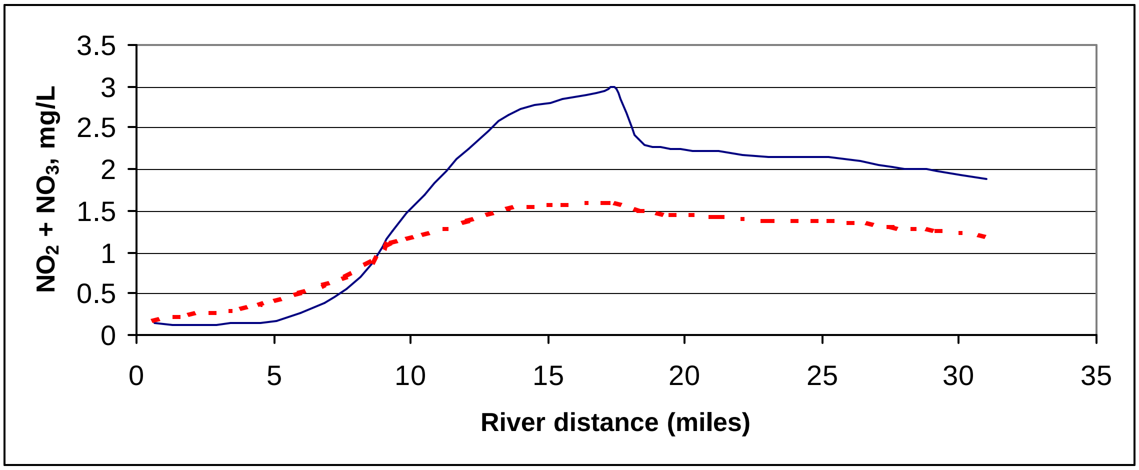


Figure A46: Organic Nitrogen vs. River Mile for the Future Low Flow TMDL Scenario

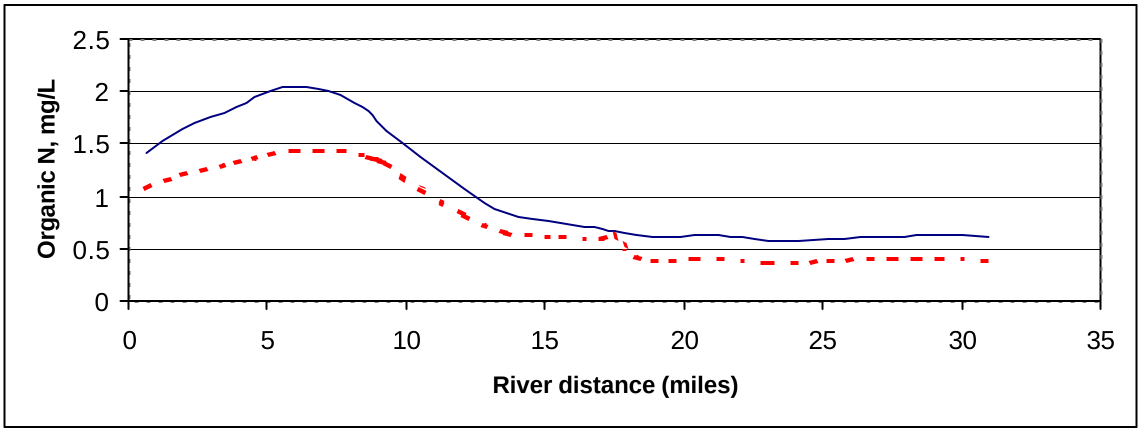
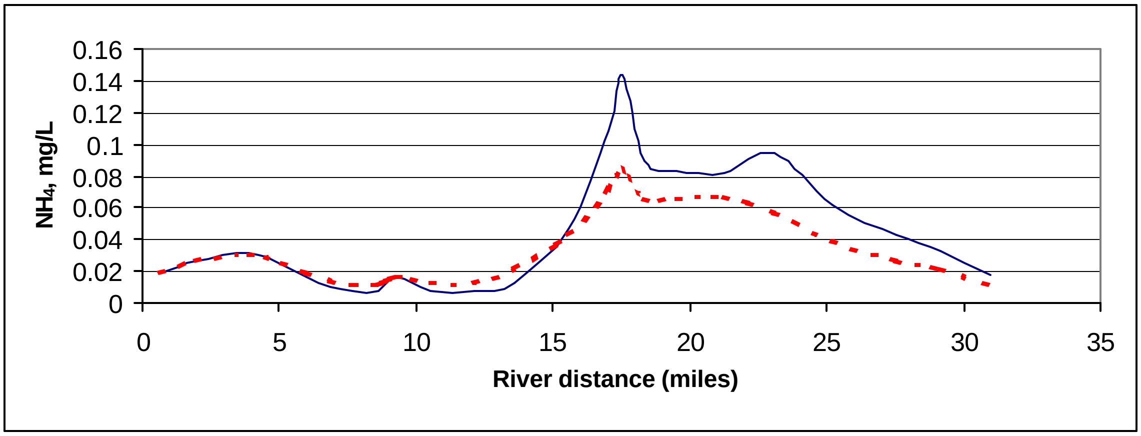


Figure A47: Ammonia vs. River Mile for the Future Low Flow TMDL Scenario



——— **Baseline Conditions Low Flow Scenario** ┈┈┈ **Future Low Flow TMDL Scenario**

Figure A48: Organic Phosphorus vs. River Mile for the Future Low Flow TMDL Scenario

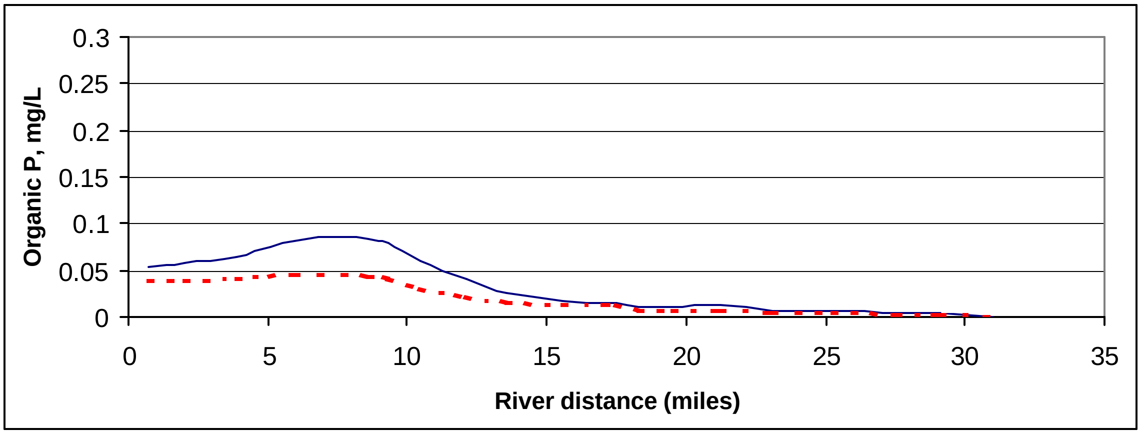
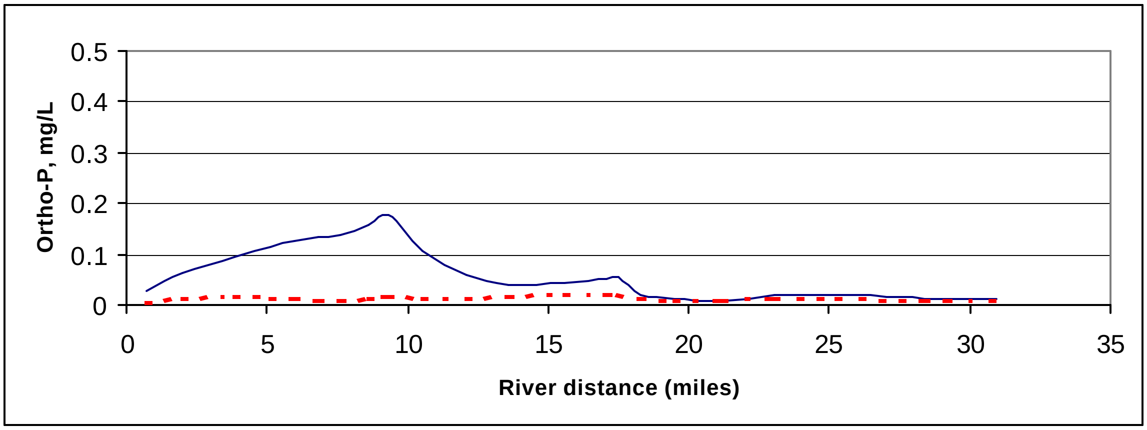


Figure A49: Ortho-Phosphate vs. River Mile for the Future Low Flow TMDL Scenario



Baseline Conditions Low Flow Scenario **Future Low Flow TMDL Scenario**

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